THE GEOGRAPHIC SOCIETY OF CHICAGO
BULLETIN No. 1

THE GEOGRAPHY OF CHICAGO AND ITS ENVIRONS

BY
ROLLIN D. SALISBURY
AND
WILLIAM C. ALDEN

REVISED EDITION

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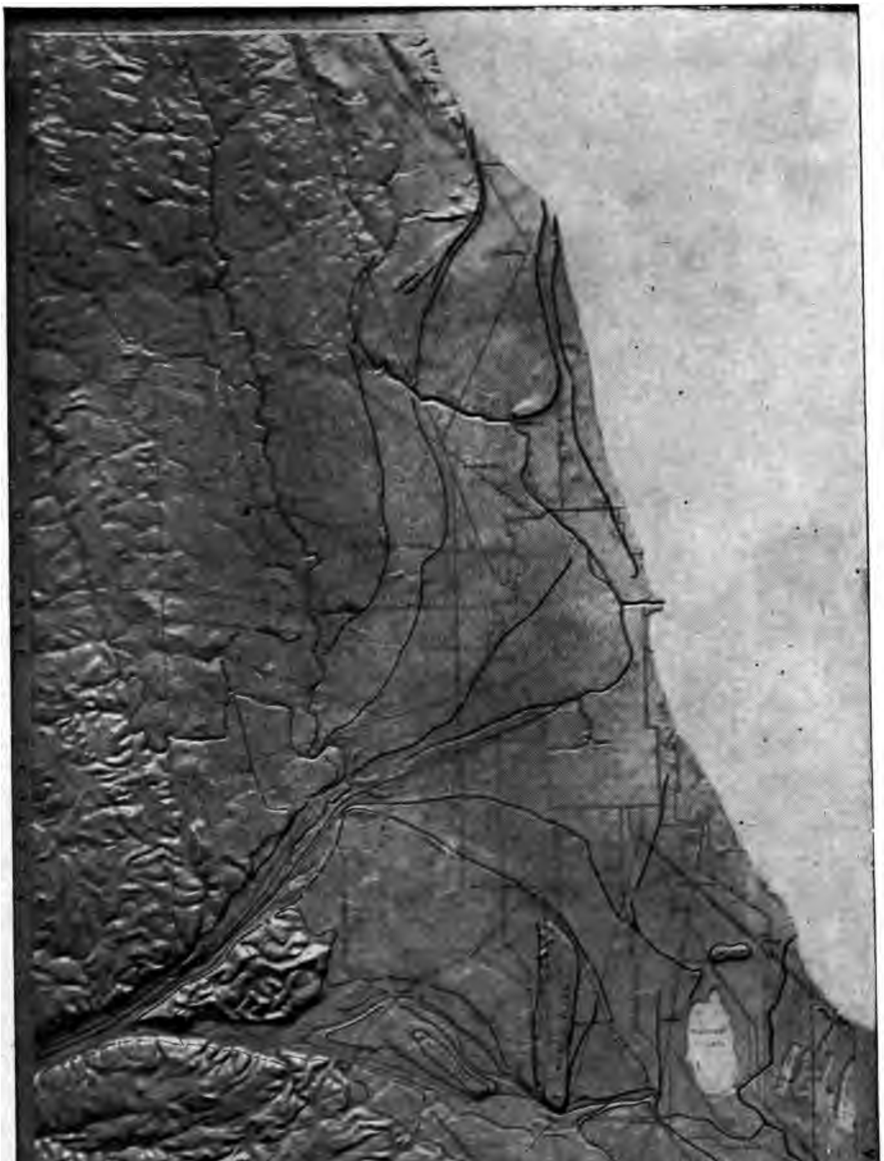
PLATE I



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PREFATORY NOTE

It is the purpose of this essay to present an outline of the geography of Chicago and its immediate surroundings, and especially to sketch in as simple a manner as possible the course of events by which that geography was developed. The essay is not intended to take the place of the detailed descriptions of special localities heretofore published or yet to be published. Rather is it meant to give such an account of the region about the city that the interpretation of local phenomena may be more easily and more generally understood.

Much of the detailed field work on which the text is based was done by the junior author. Some of the data were gathered by him under the auspices of the United States Geological Survey, during his preparation of a map of the surface geology of the region, and are here used through the generosity of the Survey. Obligations for the use of these data are hereby acknowledged.* Some of the data were gathered by Mr. Leverett, and published by him in the *Bulletin of the Chicago Academy of Sciences*, referred to in the following pages. Acknowledgment is also made of indebtedness to the work of earlier students, whose names are mentioned in the course of the essay. In this second edition more attention is given to the dunes than in the first.

In the preparation of the illustrations valuable assistance was given by Professors Wallace W. Atwood, Henry C. Cowles, and Frank H. Harms, and Miss Evelyn Matz. The frontispiece is from a model made by Mr. C. E. Siebenthal.

The second edition of this *Bulletin* gives a somewhat fuller statement concerning the dunes, which have become the object of much interest to Chicago and to the larger community of which Chicago is the center.

April, 1920

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CHAPTER I

THE CHICAGO PLAIN

TOPOGRAPHY

General topographic relations.—The topography of a region is always significant of its history. The city of Chicago is situated on a low, strikingly flat plain, bordering the west side of the head of Lake Michigan. The limits of the plain for a tract about the city are shown in Figure 1 (also Plate I, Frontispiece), from which it will be seen that the plain is roughly crescentic. Its inner border is formed by the shore of Lake Michigan, while its outer margin, marked by higher land (shaded in Fig. 1), extends from Winnetka on the north, through Galewood and La Grange on the West, to Glenwood and Dyer (Indiana) on the southwest and south. Its greatest width is about 15 miles in a direction southwest from the city.

Back from the shore of the lake, the level of which is about 581 feet above mean tide level in New York harbor, the Chicago plain rises very gradually to a nearly uniform height about 60 feet above the lake. At this level the flatness of the plain is interrupted, and to the west and south the surface rises promptly, and its topography is rolling. The rise is continued until the rolling surface reaches an extreme altitude about 200 feet above the lake. From this considerable elevation there is a decline toward the west, southwest, and south. In other words, the Chicago plain is shut in by a very broad, ridgelike belt of higher land of gently rolling topography. Observations beyond the immediate vicinity of Chicago show that this belt of higher land continues northward into Wisconsin, and swings eastward about the head of the lake basin. It is in reality a great glacial moraine, and has been called the Valparaiso moraine from the city of Valparaiso (Indiana), which is situated upon it. Where crossed by the Wabash Railroad southwest of Palos Park (=Palos Springs on Plate II), this moraine has a width of 15 miles, its outer edge being at New Lenox. These relations are shown on the accompanying maps (especially Plate II), to which constant reference should be made. North of the line of the Chicago, Burlington & Quincy Railroad the moraine is ill-defined, and the location of its eastern border is somewhat arbitrary.

Cutting directly across this low, broad ridge in a southwesterly direction, from Summit to Lemont, is the valley now traversed by the Des Plaines River, the Illinois-Michigan Canal, and the Drainage Canal.

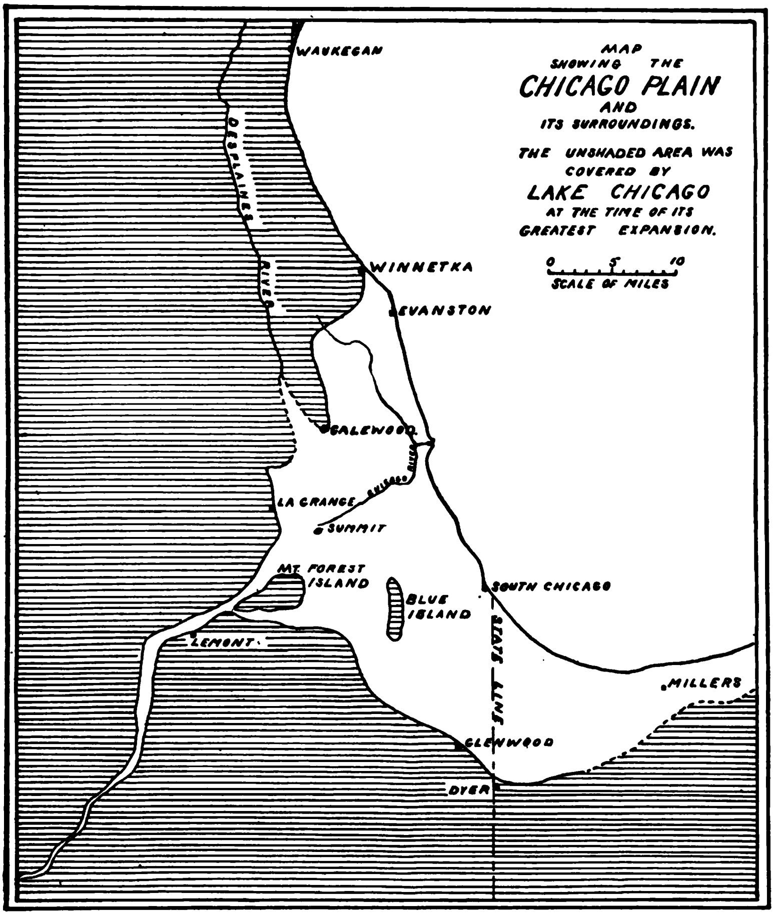

FIG. 1.—The Chicago plain (the area of land not lined) and its surroundings

This valley has abrupt slopes, varies in width from one-half mile to one and one-fourth miles, and is 30 to 100 feet deep. The floor of this valley is nearly flat. At its lakeward end the bottom is continuous with the Chicago plain, and is less than 15 feet above the level of the water in the

lake. These relations are shown in the Frontispiece, in Plate II, and in Figure 1. From Summit to Lemont the fall of the river is so slight as to be spoken of as "the twelve-mile level."

Tributary to this valley at Sag Station, about three and one-half miles above Lemont, is a second valley of like dimensions known as "the Sag." This valley extends nearly due west from the village of Worth on the Wabash Railway, to Sag Station on the Chicago & Alton Railway. It was traversed formerly by a small creek known as the Canal Feeder, but a canal now passes through this valley. The Sag and the valley to the north converge and unite at Sag Station, including between them a triangular tract of elevated land of undulating topography. This isolated area, known as Mount Forest, has a length of six miles and a width of four. On this island it is understood that an arboretum is soon to be established.

The floor of the Sag, as well as that of the Des Plaines Valley, is continuous with the Chicago plain. These two valleys, therefore, give ample outlet for drainage from the Chicago plain southwestward across the moraine belt, and thence by way of the Illinois and Mississippi rivers to the Gulf of Mexico. Along the course of the canal there was a rise of less than 15 feet from the present level of the lake to the divide which separated the lake from the Des Plaines River before the canal was made. The lake, therefore, barely escaped drainage into the Mississippi River system, even without the canal.

Topography of the plain.—Apart from the Mount Forest Island already mentioned, the most prominent topographic feature of the plain is the Blue Island Ridge (Plate II), seven miles west of the lake at South Chicago. The course of this ridge is nearly due north and south. It has a length of six miles, a width of about one mile, and an elevation of 25 to 50 feet above the surrounding flat.

Just west of South Chicago, between the north end of Blue Island Ridge and the lake, is a minor elevation of rock known as Stony Island (S.I., Plate II). Its longer axis has an east-west direction. The length of the "island" is one and one-fourth miles, its width about half a mile, and its height about 20 feet above its surroundings, which are low and marshy except where drained by man.

Traversing the plain, and converging to the two southwestward valley extensions of the plain on either side of Mount Forest, are a series of low ridges of sand and gravel so related to the lake, to the valleys on either side of Mount Forest, and to one another, both in elevation and

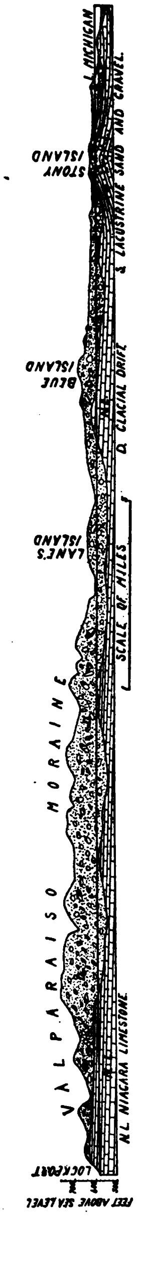

FIG. 2.—Section from Lockport to South Chicago

arrangement, as to be most significant in working out the geographic history of the region. In parts of the city where the natural surface has not been destroyed by grading, as well as at many points outside the city, these low ridges are brought into prominence by the native oak trees which grow upon them, while their surroundings are treeless. Some of these inconspicuous ridges are shown on Plate II.

Apart from these features, some of which are not pronounced, the notable characteristic of the topography of the plain is its flatness.

STRUCTURE OF THE PLAIN

Relations of rock and drift.—The sub-structure of the Chicago plain is solid rock. This may be seen in the several quarries about the city, and is made known by deep borings and excavations of other sorts at many points where the rock is not exposed at the surface.

Overlying the bed-rock is a mantle of unconsolidated material composed of bowlders, gravel, sand, and clay collectively known as "drift." Borings for wells, excavations for the foundations of buildings, and the exposures of rock in the quarries show that the thickness of the drift mantle is extremely variable, and since the surface of the plain is nearly flat, it follows that the surface of the rock on which the drift rests is very uneven (Fig. 2). If the drift mantle were stripped off, there would remain, instead of the flat plain on which the city now stands, a markedly uneven surface. The present rock outcrops, where the drift is thin or absent, would be the tops of hills rising above their surroundings. The areas where the drift is thick would appear as valleys or depressions among the hills. Some of the slopes from the hilltops to the valleys about them would be steep and some gentle. City Engineer Samuel G. Artingstall once prepared a map of the city giving the elevation of the rock surface at various points, as shown by borings. While the data

for this map were insufficient to determine details of the topography of the rock, the map showed clearly the undulatory character of its surface, and the consequent varying thickness of the drift, not only in the plain, but also over the area beyond the plain, where the drift surface is undulatory.

The lowest level of the rock surface determined is near the North Branch of the Chicago River, about half a mile north of its junction with the South Branch. The surface of the rock is here 124 feet below the level of Lake Michigan. Passing out radially from this point the rock surface rises, with many undulations and numerous exposures at the surface. This rise in the surface of the rock is continued under the moraine surrounding the Chicago plain, until it reaches an elevation of 100 to 110 feet above the lake level.

While the rock surface is higher outside the Chicago plain than beneath it, the elevation of the surrounding country above the Chicago plain is not due entirely to this cause. From the study of one hundred borings distributed over the plain, it has been estimated that the average elevation of the rock surface under the plain is 45 to 50 feet below the level of the lake. From about sixty borings west and southwest of the plain in the area of higher land with rolling topography, the average elevation of the rock under the moraine-covered territory has been estimated to be 25 to 30 feet above the level of the lake. This makes the elevation of the rock 70 to 80 feet greater under the higher land outside the plain than under the plain itself. In the plain the drift varies from 0 to 130 feet in thickness, with an estimated average of 50 feet. In the moraine belt the average thickness of the drift has been estimated at 150 feet. It is thus evident that the belt of higher land above the Chicago plain is due partly to a rise in the surface of the rock beneath it, and partly to the greater thickness of the drift (Fig. 2).

The rock.—The rock beneath the plain about Chicago is limestone. At the various quarries and wherever the rock is exposed it may be seen to contain pieces of coral, fragments of crinoid stems, and fragmentary or perfect shells of various types of shell-bearing life. Locally, the limestone may almost be said to be made of such fragments, large enough to be seen by the unaided eye. These fossils give positive evidence of the origin of the limestone, for all of them are the relics of life which lived in sea water. In the ocean today similar accumulations of coral and shells are making, where the conditions are favorable. Geologists are therefore confident that the limestone of this region was accumulated

beneath the sea, and this means that the ocean covered the site of the city when the limestone was formed.

By means of its fossils, and by other means less readily explained, the age of the limestone, in terms of geological chronology, is known. It belongs to the later part of the Silurian period, and the Silurian is the third of the seven long periods which make up the Paleozoic era, the first era when, so far as now known, there was abundant marine life. The local rock is known as the *Niagara limestone*, because it is believed to be of the same age as the limestone at Niagara Falls, and the limestone at that point was long since named Niagara.

The limestone may be seen at all the quarries about the city. There are good exposures at or near Stony Island, Hawthorne, Bridgeport, Elmhurst, Lyons, and Thornton.

Until recently no formation of rock (barring the drift) younger than the Niagara was known in the immediate vicinity of Chicago; but Professor Stuart Weller has found remnants of a formation of the Devonian period (the period next following the Silurian) at the quarry a mile west of Elmhurst. Meager as these remnants are, they show that beds of Devonian age once overlay the Niagara limestone. Like the Niagara formation, these Devonian remnants are of marine origin, and prove the existence of the sea in this region in the Devonian as well as in the Silurian period. The waters of the Silurian and Devonian seas in this region probably were not deep. Their shallowness is suggested by the character of the fossils. For example, corals do not flourish in deep waters, and corals are abundant in the Niagara limestone. It is probable that still younger beds (the Mississippian) once overlay the Devonian in this region. Good evidence that this is the case has been found.

THE DRIFT

The best large exposures of drift may be seen along the lake bluff from Evanston northward, and at the clay pits of the various brickyards in and near the city. Some of these pits, accessible from various parts of the city, are the following: near the North Branch of the Chicago River, west of Lincoln Park; in the vicinity of South Robey and Forty-third streets; west of the Union Stock Yards; and at Purington Station on the Chicago, Rock Island & Pacific Railway.

Apart from these exposures, which are more or less permanent, temporary exposures are frequently to be seen at various points in the city where excavations are being made for the foundations of buildings,

for water-pipes, gas-pipes, etc. Good exposures were to be seen along the drainage canal when it was made, and now along the line of the new canal which traverses the Sag.

Unstratified drift.—The drift at different points presents various characteristics. In most of the localities where the more permanent

FIG. 3.—A typical section of glacial drift, or till. (Atwood)

exposures occur, the drift consists of a matrix of dense blue (in places buffish) clay, in which are imbedded many stones (Fig. 3). In size the stones range from pebbles to bowlders several feet in diameter. The material is in general without arrangement; that is, the fine and the coarse are intimately mingled. To put the matter in another way, the drift does not show the assortment and stratification characteristic of

deposits made by water. Much of the stony material is too coarse to have been handled by waves or currents of any ordinary strength.

The greater part of the stony material of the drift was derived from the Niagara limestone which underlies the drift, not only about Chicago, but throughout northeastern Illinois and eastern Wisconsin as well. Another but smaller portion is composed of fragments of sedimentary rock from other formations, while still another part consists of fragments of metamorphic and igneous rock. More commonly than otherwise the larger bowlders belong to this last class, and the formations from which they came are found about Lakes Superior and Huron, and other points to the north and northeast.

If the stones imbedded in the clay are examined, they are found to be partly angular and partly rounded, but largely sub-angular, with numerous flat surfaces or facets (Fig. 4). They show neither the rounding of shore pebbles nor the angularity of freshly broken rock. The facets often show polishing, parallel grooving, and scratching, as though smoothed and striated while being held in a firm position, and moved over a hard surface beneath.

The fine material of the unstratified drift, that is, the blue clay (which is in most places yellowish at the surface), is found on examination to be made up of minute particles of rock. It is, in fact, nothing more than finely pulverized rock. Particles from many sorts of rock enter into its composition, though some are abundant and some rare. About Chicago particles of limestone are by far the most abundant. Their presence in abundance is easily shown by putting a few drops of hydrochloric acid on the blue clay. It will, as a rule, effervesce briskly. The effervescence is the result of the decomposition of the lime carbonate by the acid, the carbon dioxide of the former escaping, and causing the bubbles.

The surface portion of the clayey drift to the depth of two or three feet is buffish or yellowish in color, in most places. This portion does not, as a rule, effervesce when acid is applied, showing that it does not contain much lime carbonate. The explanation of the buff, non-calcareous surface portion will appear later.

As will be seen from the list of localities enumerated above, unstratified drift occurs in some places on the low, flat plain, and in some places on the high, rolling land which borders it. In many places it is known to run down far below the level of the lake, lying on the rock with no stratified drift beneath.

In some places about the city, and at numerous points throughout the drift-covered area, bits of timber and even large logs are found in the drift. Vegetable mold and beds of peat, which represent buried swamps, are also found both about Chicago and throughout the broader area of which this forms a part. These logs, beds of peat, etc., record the fact that as the glacier ice which made the drift advanced over the region, it found forests, soils, and swamps. Trees were broken and carried forward by the ice and incorporated with its stony and earthy débris. The soils and the peat of the swamps in some cases suffered a similar fate, but since they offered little resistance to the ice, they were in some cases overridden and buried, without being carried forward. It is manifest that, if the species of the plants could be determined, they would give some clue as to the climate preceding the advent of the ice.

Stratified drift.—In many parts of the city, and at many points outside the city on the Chicago plain, the shallow excavations which are to be seen show that the upper part of the drift consists of sand and gravel, instead of clay

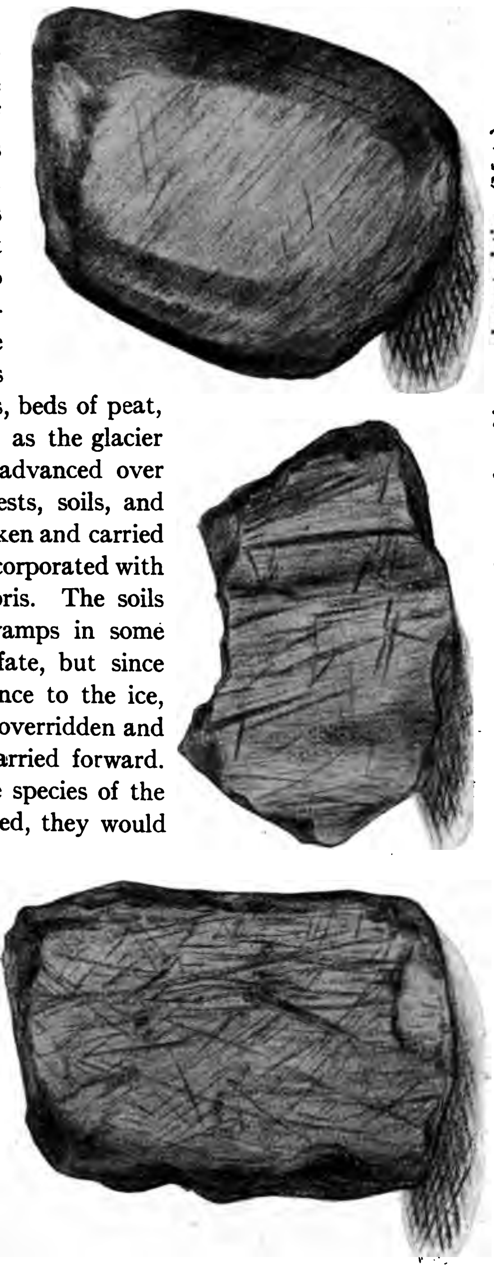

FIG. 4.—Glaciated stones from the drift of Chicago. Both shapes and marking are characteristic. (Matz)

and stones, and that the sand and gravel are stratified. If the excavations are deep, the blue clay with its content of stones is in places exposed beneath the sand and gravel. Many of the stones of

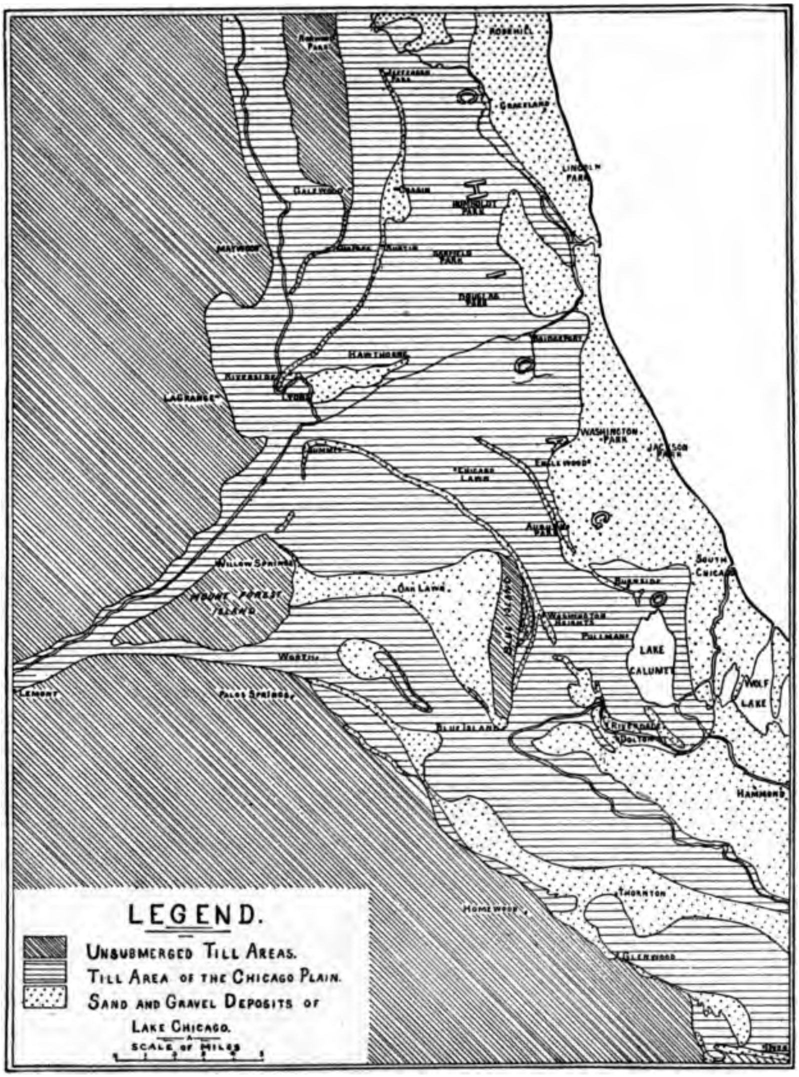

FIG. 5.—Map showing the general distribution of (1) stratified sand and gravel and (2) unstratified drift (till) on the surface of the Chicago plain.

the stratified drift are rounded, and very few striated. This superficial mantle of stratified drift is wanting in many parts of the plain. The stratified drift is, however, not strictly confined to the plain. At the south end of the Blue Island Ridge, for example, there is a considerable body of stratified drift running well up toward the summit of the elevation. Nor is the stratified drift all at the surface, though this is where it is most commonly seen. Some deep excavations show thin beds of stratified drift below thick or thin bodies of unstratified. A complete explanation of the drift must of course take account, not only of the unstratified drift, but of the stratified drift in all its positions and relations.

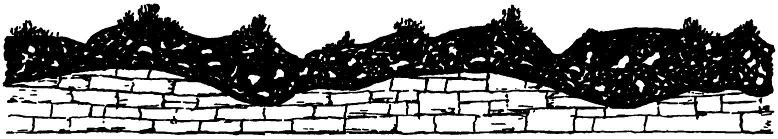

FIG. 6.—Diagrammatic section, showing the relation of drift to bed-rock

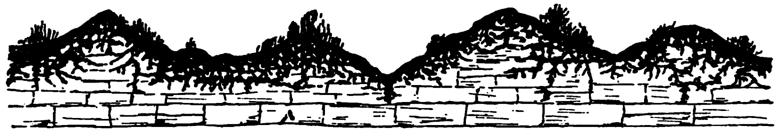

FIG. 7.—Diagrammatic section, showing the relation of residuary earths to the rock on which it lies, and from which it has arisen by decay.

The general distribution of stratified drift on the surface of the plain is shown in Figure 5.

Surface of the rock beneath the drift.—These various characteristics of the drift, stratified and unstratified, are hardly less significant, in the explanation of the phenomena about Chicago, than the surface of the limestone beneath. In general it may be said that the surface of the limestone, where it is accessible, is relatively smooth. This statement is not to be confused with the idea already distinctly stated that the surface of the limestone is very uneven. What is here stated is that the surface of the limestone over an elevation or in a depression is, for any small area, essentially smooth (Fig. 6). When the limestone is uncovered its surface frequently looks as if it had just been smoothed or polished. It has not the numerous little irregularities which characterize the surface

of limestone which has decayed under the influence of atmospheric changes (Fig. 7). In such cases the surface of the limestone is irregularly etched, and in places so soft and crumbling that an exact line marking the distinction between the earthy matter above and the rock below cannot be drawn; but beneath the drift the surface of the limestone is in general hard as well as smooth, and the demarcation between it and the drift is perfectly definite. Figures 6 and 7 put the two types of rock surface in contrast.

FIG. 8.—Abandoned quarry at west end of Stony Island. The figure shows the dip of the rock and the general smoothness of its upper surface. The striae on the surface do not show. (Harms.)

Not only is the surface of the rock beneath the drift hard and in general smooth, but it is also marked by numerous lines and grooves comparable to the lines and grooves on the surfaces of the stones of the drift. So striking is the correspondence between these marks on the bed-rock and those on the stones of the drift, that there can be no doubt that they owe their origin to a common cause. Furthermore, the striae which are to be seen on the surface of the limestone beneath the drift are, in any locality, essentially parallel to one another.

The characteristics which have been mentioned as affecting the surface of the limestone, as well as many other phenomena which need not be here detailed, indicate that the limestone was worn in such a way as to smooth and striate its surface *at the time the drift was deposited.*

The arrows on the map, Plate II, show the location of the striae which have been observed about Chicago, and their direction. Striae may be seen on the surface of the rock at the east side of the abandoned quarry near the west end of Stony Island. The striae here affect the upturned edges of strata which have been planed down, as well as polished and scratched. Here as elsewhere striae are to be seen on the

FIG. 9.—Old quarry on the south side of Stony Island. The surface shown in the figure does not show the striae, though it shows the general smoothing which characterizes glaciated surfaces. Near the right-hand side of the figure near the bottom the rock overhangs. On the overhanging surface grooving is seen, and striae may be seen in the field. (Harms.)

surface of the rock only where the drift has been recently removed. Surfaces of limestone which have long been exposed do not show striae. At the old quarry on the south side of Stony Island striae may be seen on vertical and even on slightly overhanging surfaces.

Other easily accessible localities which show glacial striae, or which have shown them in recent years, are the following: (1) in the vicinity

of the intersection of Chicago Avenue and Western Avenue; (2) at Robey and Nineteenth streets; (3) at the quarry of Dolese & Shepard at Hawthorne Station; (4) at the Lyons quarries, south of Riverside; (5) in the bed of the Des Plaines River at low water, between Riverside and Summit; (6) at the quarries at Summit; (7) at the quarry a mile west of Elmhurst; and (8) in the bank of the creek south of the bridge at Thornton.

Some other localities are shown on the map, but either the striae are not good, or they are not now easily accessible. It is probable that striae may not be seen readily at some of the places mentioned, for they disappear by the weathering of the surface of the limestone if it is long exposed. In places, too, rock which once showed them has been removed or covered.

The features of the drift and of the rock surface beneath which have been mentioned as characterizing the region about Chicago, hold, in a general way, over all the millions of square miles of territory which the drift affects; and the conclusions which follow are based, not on the phenomena about Chicago alone, but on the phenomena of this greater area, much of which has been studied with great care.

The drift is of glacial origin.—The characteristics of the unstratified drift, together with the characteristics of the surface of the rock on which it lies, point in no uncertain way to this conclusion. The drift is identical in kind with the deposits now being made by glaciers in various parts of the world, and the characteristics of the surface of the rock beneath the drift are identical with those of the surface of rock over which glacier ice is known to have passed recently. This is made clear by the fact that in many regions existing glaciers are diminishing in size, and are therefore bordered by areas which they recently covered, but from which the ice has now melted. In such situations both the débris deposited by the ice (the drift) and the surface of the rock on which it rested recently are accessible. Here the surface of the rock is found to be smoothed and polished, and marked by lines or grooves essentially parallel to one another. On it rests a mantle of débris of variable thickness, made up of bowlders or smaller pieces of rock, imbedded in a clayey matrix composed of pulverized rock, the mixture being without stratification. The stones are more or less faceted and striated. With this unstratified débris there is some which is stratified.

Furthermore, the lower portion of existing glaciers in places may be seen, and the lower part of the ice is thickly set with a quantity of earthy,

sandy, and stony material of all grades of coarseness and fineness. With these materials imbedded in its lower portion, the ice moves forward slowly, resting down on the surface over which it passes with the whole weight of its mass. The grinding action between the stony matter in the bottom of the ice and the rock bed over which it moves is powerful. The coarse material in the bottom of the ice grooves and scratches the bed over which it is borne, while the fine material, like clay, polishes the surface over which it is moved.

At the same time that the material is carried forward in the bottom of the ice and used to grave the surface of the rock beneath, the stones in transit are themselves worn, for the bed-rock reacts on them. Like the bed-rock, they are striated. One surface of a stone in the ice is at one time held against the bed-rock and worn flat and polished or striated. The stone may then be turned, and in the new position a new flat surface may be developed. The stones in the ice may be worn, not only by the bed-rock, but by one another. Thus they may be striated on several or all sides, and because the stone may change its position from time to time, the striae may run in any direction (Fig. 4). The bed-rock, on the other hand, not being free to move, is striated in one direction only. Its striae, therefore, and not those of the stones of the drift, show the direction of ice movement after the ice has melted.

So unique and so distinctive are the results of the work of glacier ice that they cannot be mistaken for the work of any other agency; and so many and so striking are the points of correspondence between the work of existing glaciers and the work of the agencies which produced the drift about Chicago (and the large drift-covered area about it), that there is no escape from the conclusion that the latter, with all its accompanying phenomena, is the work of glacier ice.

In the valleys and on the plains beyond the existing glaciers there are in places deposits of stratified sand and gravel, borne out beyond the ice by waters which came from its melting. Water action necessarily accompanies glacier action, and the deposits made by water are stratified. Every glacier, therefore, gives rise to water, which is sure to stratify more or less of the material which the ice had deposited, or which it was carrying. It is through the agency of water, therefore, that the stratified drift accompanying the unstratified is to be explained. It will be seen in the sequel that the water which stratified the drift may be lake or sea water, as well as that of streams.

CHAPTER II

DEVELOPMENT OF THE PRESENT GEOGRAPHY

The preceding pages should have made it clear that two formations determine the geography of Chicago. These are (1) the rock beneath the surface, and (2) the drift which lies above it.

THE GEOGRAPHY OF THE ROCK SURFACE

After the Niagara limestone was deposited, and after such younger beds as once covered it had been laid down upon it, the sea retired from this region, either because its waters were drawn off by the sinking of the deeper parts of the ocean bottom elsewhere, or because this section of the earth's crust was warped upward sufficiently to bring it above the level of the water. So soon as it became land, its surface was exposed to the action of heat and cold, rain and wind, and plants and animals. Of primary importance was the rain, and the streams to which the rain gave rise. These streams, working as streams have always worked, began to cut valleys in the surface of the land, and ultimately wore away much of the rock, carrying the eroded material back to the sea. During the long period which followed the deposition of the youngest marine beds, almost all of the formations down to the Niagara limestone were carried away by erosion. Not only were the formations above this limestone destroyed, but the surface of the limestone itself was deeply eroded by the same processes which had carried away the overlying beds. The cutting of valleys in its surface left ridges and hills between them, and the surface at the close of the long period of erosion was even rougher than that which now affects the limestone beneath the drift.

In northwestern Indiana the Niagara limestone is overlain by Devonian formations. At the junction of the Des Plaines and Kankakee rivers is found the northeast margin of the formations of the Mississippian (Lower Carboniferous) system (next younger than the Devonian), which covers most of the state, while farther west, in Iowa and beyond, the systems of the Mesozoic and early Cenozoic eras overlie the Carboniferous. The mantle of drift which covers the Niagara limestone of Chicago covers all these younger systems of strata. It is therefore evident that all the vast geologic periods represented by these several

younger systems of rock must have intervened between the deposition of the Niagara limestone and the deposition of the mantle of drift which rests on its surface. These relations show that the period of erosion following the deposition of the Devonian and Mississippian beds, and preceding the deposition of the drift, was very long.[1]

THE GLACIAL PERIOD

The long period during which the rock beneath this region was exposed to the ordinary agencies of rock disintegration and erosion was brought to a close by climatic changes the like of which had never occurred in this latitude, so far as now known, in all the earth's history. This change consisted in the development of arctic conditions, not only about Chicago, but over a wide area in the northern and northeastern parts of the United States, as well as over a still larger area farther north. Under the influence of these conditions, a vast continental ice-sheet, comparable to that which now covers Greenland, though many times larger, came into existence. Its area, when at its maximum, is represented in Figure 10. The cause of the climatic change which brought about the glacial conditions is not here discussed. Conjecture has attributed it (1) to great changes in the orbit or axis of the earth, (2) to changes in the elevation or distribution of the land, (3) to changes in the constitution of the atmosphere, as well as to many other changes, real or speculative. Suffice it to say that scientists are not agreed as to the hypothesis which best explains the facts, but the hypothesis which assigns the change to variations in the constitution of the atmosphere is now most in favor. Whatever the cause, the fact that a great ice-sheet, about 4,000,000 square miles in area, came into existence in the northern part of the continent, is no longer open to question. As already pointed out, the proof is found in the character of the drift, and in the peculiar and distinctive features of the rock surface beneath it.

Careful and extensive study of the drift in North America has led those geologists who have concerned themselves especially with the drift, to the confident conclusion that the glacial period consisted of several more or less distinct glacial epochs, separated by epochs which have

[1] This period of erosion is here spoken of as if it were uninterrupted, though this may not have been the case; but for our present purpose it is not important to recite the many elevations and depressions, and perhaps the submergences and emergences, which this region is known or thought to have suffered since the deposition of the Devonian and Mississippian beds.

FIG. 10 shows the area covered by ice during that epoch of the glacial period when the ice was most extensively developed. The main centers of accumulation are also shown. There were many small centers of glaciation in the mountains south of the main ice-sheet. (After Chamberlin.)

been called interglacial. During the glacial epochs the climate was severe, and the ice-sheets were enlarged; during the interglacial epochs the climate was less severe, and the ice-sheets diminished in area and thickness, if indeed they did not disappear altogether. During these mild intervals plants and animals returned to latitudes from which they had been driven by cold and ice, only to be driven southward again with the advent of the next epoch of rigorous climate.

The most extensive invasion of the ice reached the Ohio River in Ohio and Indiana, and farther west reached northeastern Kansas. West of that point the margin of the ice was not very distant from the Missouri River.

The ice-sheets of several of the glacial epochs passed over northeastern Illinois, and each contributed to the aggregate effects of glaciation. In the paragraphs which follow, it is the effects of glaciation, rather than the effects of the ice of any one glacial epoch, which are referred to; yet the effects of the last glacial epoch on the geography of Chicago are of so much more importance than those of the others that chief emphasis is laid on its results. It should be noted, however, that some of the great geographic features of the region, such as the basin of Lake Michigan, may have been formed before the latest advance of the ice, perhaps much before.

Development of the ice-sheet.—The special feature of the glacial period was an ice-sheet of continental dimensions. The climatic change which preceded and caused the development of this ice-sheet probably came on gradually, and the growth of the ice-sheet probably was slow. To gain a conception of the origin of the ice-sheet a few familiar principles may be recalled.

The temperature and the snowfall of a region may stand in such a relationship to each other that the summer's heat may barely suffice to melt the winter's snow. If under these circumstances the annual temperature were to be reduced, or the fall of snow increased, the summer's heat would fail to melt the winter's snow, and some portion of the winter's snow would endure through the summer. Were this condition once inaugurated, the depth of the snow would increase from year to year, and at the same time the area of the snow-field would be enlarged, since the presence of the snow would so far reduce the temperature of the surrounding territory as to increase the proportion of the precipitation which would fall as snow. In the course of time, and under favorable conditions, the area of the snow-field and the depth of the snow would

become great. If at the same time the climatic changes which occasioned the snow-field continued to act with increasing effect, the total result would be still greater.

As in the case of snow-fields today, the greater part of the snow-mass would be converted into ice eventually. Several factors must have been effective in accomplishing this result. The pressure of the overlying snow would tend to compact the lower portions of the snow into ice, and water arising from the melting of the surface snow by the sun's heat, and percolating through the superficial layers of the snow, might freeze below, taking the form of ice. By these and other changes the snow-field becomes an ice-field, the snow being restricted to its superficial parts.

Eventually, increase in the depth of the snow gave rise to other phenomena. After the thickness of the ice became considerable, the pressure upon its lower parts was great. We are wont to think of ice as a brittle solid. If in its place we had some slightly plastic body, which would yield to pressure, it is evident that the weight of the overlying portions would press out the lower parts of the mass, and that these would spread in all directions by a sort of flowing motion.

Under great pressure many substances which otherwise appear to be solid exhibit some of the characteristics of plastic bodies. Among the substances exhibiting this property, ice is, perhaps, best known. Brittle and resistant as it seems, it may be molded into almost any desired form if subjected to sufficient pressure, steadily applied through long intervals of time. The changes of form which may thus be produced in ice are brought about without visible fracture in its mass. The exact nature of the movement which takes place between the particles probably does not correspond to the movement between the particles of a viscous fluid, but the result appears to be much as would have been brought about if the ice were capable of flowing, with extreme slowness, under great pressure continuously applied. One of the chief factors in the movement of glacier ice probably is the refreezing of the water in the ice. This refreezing, with the attendant expansion, thrusts the ice in the direction of easiest movement. This is down slope, for in this direction gravity helps. In an ice-sheet, down slope is toward the edge of the ice. The water in the ice which refreezes is either water formed by the melting of the surface ice, or water formed in the ice by the friction of movement.

In a great ice-field we have the conditions for great pressure and for its continuous application. The result is that the great weight

of ice, pressing down upon the lower parts of the ice-field, induces a gradual movement of the ice outward from the deepest part of the field, so that areas surrounding the region of great snow and ice accumulation are gradually encroached upon by the ice. Observation shows that this is what takes place in every snow-field of sufficiently great extent and depth. Motion thus brought about is glacier motion, and ice thus moving is glacier ice.

Greenland affords an example of the conditions here described. A large part of the half-million square miles which this body of land is estimated to contain, is covered by a vast sheet of snow and ice, hundreds and thousands of feet in thickness. In this field of ice and snow there is continuous, though very slow, movement outward toward its borders. The edge of the ice is where the waste (melting and evaporating) of the ice is counterbalanced by its advance.

The edge of an ice-sheet does not remain fixed in position. There is reason to believe that it alternately advances and retreats, according as the ratio between movement and waste increases or decreases. These oscillations in position are believed to be connected with climatic changes.

The ice-sheets of northeastern North America appear to have had more than one center of growth. One main center lay east of Hudson Bay, and another west of it (Fig. 10). There were perhaps other minor centers, but ultimately the snow-fields, extending themselves from their several centers, united, and the resulting ice-sheet is commonly spoken of as a unit.

In addition to the ice-cap of the northeastern part of the continent, there was an ice-sheet in the northwestern part. This extended eastward from the mountains and joined the one originating farther east, near our national boundary, in the longitude of Montana.

The centers of ice accumulation were, on the whole, a little higher than their surroundings except to the west of the Keewatin center (Fig. 10), so that if the relative elevations of the different parts of the continent were the same as now when the ice was here, the ice moved from higher to lower lands, except along the western border of the Keewatin sheet. The surface of the land is, however, so uneven, and its inclination so slight, that some cause of movement other than its slope must be involved. Furthermore, since the ice passed over valleys, hills, and even mountains, without having its general direction of movement notably affected by them, it is clear that its motion was not controlled primarily by the slope of the surface on which it rested.

The direction of flow[1] of any liquid substance depends, not immediately on the slope of its bed, but on the slope of its upper surface. For the surface of the ice to have had sufficient slope to cause the movement, its thickness must have been great. The limit of the ice in southern Illinois is something like 1,600 miles from the center of the ice-sheet. How much slope of the upper surface would suffice to cause the movement which actually took place?

Various estimates of the slope of the surface of the ice have been made. If the slope were no more than 10 feet per mile, and this seems like a very moderate estimate, the thickness of the ice would have been some 16,000 feet at the center of accumulation, *if this slope held from margin to center*. It is possible that even this low angle of slope is excessive as an average. Near the margin of the ice-sheet, and this is the only place where its former surface slope can be determined now, the slope was certainly much greater than this, but with increasing distance from the margin the slope doubtless became less.

Whatever the slope, the ice in the northeastern part of the continent was thick enough, except at its very margin, to fill all valleys and basins, and to cover all hills and ridges within its area, and some of the mountains which were covered rise 3,000 or 4,000 feet above their surroundings.

When the ice covered the region about Chicago, its surface probably was essentially smooth, and not notably affected by the topography of the rock beneath. Its surface must have been many hundred feet above the surface of the highest rock hills of the region. Though the irregularities of the rock surface probably caused deflections of movement in the lower part of the ice, its movement as a whole seems not to have been much affected by any topographic feature immediately about Chicago, unless by the lake basin itself.

The erosive work of the ice.—When the ice invaded this region, the surface probably was covered with a mantle of soil and decayed rock, and vegetation probably was growing upon it. In its movement the ice soon incorporated in its lower part much of the vegetation, soil, and decayed rock. So soon as these loose materials were removed, the surface of the rock beneath was exposed to wear, and the advancing ice polished, scratched, and grooved it by means of the earthy matter and rock fragments which it slowly but steadily carried forward. The rock fragments in the ice were themselves ground, striated, and polished at

[1] It is not asserted that the ice actually flows. This is open to question; but the result of its movement is very much the same as it would be if it actually flowed.

the same time, and perhaps crowded farther up into the ice and borne onward with the load of débris.

The wear effected by the rock-shod ice was not confined to a mere marking of the surface over which it passed. Where prominences of rock obstructed its progress, they were acted upon with a force proportional to their resistance, and suffered a corresponding measure of abrasion. They were worn most on the sides which faced the movement—that is, on their *stoss* sides. All roughnesses of surface and all projecting angles of rock, being pressed upon with especial force, would in the course of time be reduced if not obliterated. Such as escaped

FIG. 11.—Shape of a hill shaped by subaerial erosion (diagrammatic).

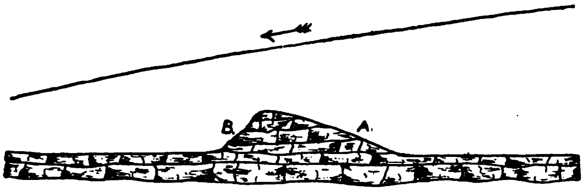

FIG. 12.—Diagrammatic figure, showing the effect of ice wear on a hill of rock, such as that shown in Fig. 11, after it has been overridden by the ice.

destruction would come to have, not merely polished and striated surfaces, but rounded forms, with the greatest wear and gentlest slopes on their stoss sides (Fig. 12). Even the minor rugosities of a glacier's bed will suffer wear in a similar manner, and, until entirely effaced, will present similar forms.

The erosive effect of the ice was therefore to grind down the elevations and to make rough surfaces smooth. The rock surface beneath Chicago and its environs still remains about as it was left by the ice. Could it be seen, it would be found to be wanting in the many little roughnesses which affect surfaces eroded subaerially.

At the same time that the hills of rock were worn down by the ice, depressions in the rock were in some cases made deeper. This is

especially true where the ice moved through a valley lengthwise. Where it crossed a valley, its effect was to wear down its borders rather than its bottom.

The moving ice must have covered the site of Chicago for long periods of time. During that glacial epoch when the advance of the ice was greatest, its stay in this region began, when, coming down from the north, it reached this latitude. Glacier ice remained over this locality while the edge of the ice was advancing some 150 miles farther south, during such time as the edge remained stationary in this advanced position, and during the time occupied in melting its edge back again to this region. If the edge of the ice advanced or retreated at the rate of but a few feet a day, it will be seen that a very long period of time, many thousands of years at least, would have been needed for it to spread from its centers to southern Illinois. During other ice epochs, when the ice advanced less far to the south, its stay here may not have been so long.

Deposits made by the ice.—On melting, glacier ice leaves its former bed covered with the débris which it carried, chiefly in its lower part. Were this material equally distributed in the ice during its motion, and were the conditions of its deposition everywhere the same, the drift would constitute a mantle of uniform thickness over the underlying rock. Such a mantle of drift would not greatly alter the topography. It would simply raise the surface by an amount equal to the thickness of the drift, leaving elevations and depressions of the same magnitude as before, and sustaining the same relations to one another. But the drift carried by the ice, in whatever position, was not equally distributed during the process of transportation, and the conditions under which it was deposited were not constant in the same area, much less in different ones. Because of the unequal amounts of material carried by different parts of the ice, and because of the unequal and inconstant conditions of deposition under the body of the ice and at its edge, the mantle of drift has a very variable thickness; and a mantle of drift of variable thickness cannot fail to modify the topography of the region it covers (see Fig. 2). The extent of the modification will depend on the extent of the variation in thickness. This amounts, in our region, to 150 feet or more, and on our continent to upward of 1,000 feet. The continental ice-sheet therefore modified the topography of the region it covered, not only by the wear it effected, but also by the deposits it made.

About Chicago the average thickness of the drift on the highlands is greater than on the low. From this it might be inferred that the relief

of the present surface about Chicago is greater than it would have been without the drift. But this is probably not the fact, for there are somewhat deep valleys in the surface of the rock beneath the Chicago plain, and they increase the relief of the rock surface notably. At any rate, the angles of slopes of the present surface are probably notably less than some of the angles of slope of the rock surface beneath the drift. Reference has already been made to the belt of thick drift which skirts the Chicago plain. The greater thickness of drift along this belt seems to have resulted from the halting of the ice edge in this position during its final retreat. If the edge of the ice had melted back at a constant rate, its position at one stage would not be marked by notably more drift than its position at another; but if its edge remained in a given position for a long time, drift was being continually brought to that position by the forward motion of the ice, and not carried beyond. Under the stationary edge, therefore, a belt of drift, thicker than that on either side, might be accumulated. This is the explanation of the Valparaiso moraine (Plate II) and of submarginal moraines in general. In its greater thickness only does it differ from the ground moraine which the great body of the drift constitutes.

Not only did the deposition of the drift affect the topography about the city by diminishing relief and by obliterating the more striking depressions in the surface of the rock, but its surface had a topography of its own. Like glacial deposits in general, its surface, as left by the ice, was undulatory, being marked by many minor and gentle elevations and depressions, many of the latter without outlets. In our own region this rolling topography, marked by low swells and basin-like or saucer-like depressions, is common outside the Chicago plain. The same topography is widespread throughout the whole area affected by drift. In the depressions lie many of the ponds and lakes which abound in the glaciated part of our country.

The topography of the region as left by the ice is then the result of the superposition of an unequally thick mantle of drift on an uneven surface of rock.

The basin of Lake Michigan.—One of the important results of the great ice-sheets, so far as this region is concerned, was the development of the basin of Lake Michigan. The basins of the other Great Lakes were formed in a similar way.

There is reason to believe that prior to the existence of the ice-sheets a great north-south river valley existed along the axis of the basin of Lake

Michigan. In passing through this valley, which probably was wide and moderately deep, the ice (1) widened and deepened it, and (2) deposited great quantities of drift along its eastern and western sides, and across it a few miles south of the southern end of the lake. Possibly also the basin was warped downward by the weight of the ice, which was thicker over the site of the lake than over the land to east and west.

When the ice melted, this deepened and widened valley, with its sides built up by drift and its southern continuation filled by drift, was a basin rather than a valley, and in it water accumulated from the melting ice. The history of the lake began as soon as the ice melted back from the southern end of the basin, and the lake increased in size as the ice withdrew farther and farther to the north, leaving more and more of the basin free.

LAKE CHICAGO

Origin.—Every ice-sheet has a period of advance followed by a period of decline. In the former the growth of the ice-field exceeds its waste, and in the latter waste exceeds growth. The duration of the last ice-sheet in this region is unknown, but it probably is to be reckoned in thousands of years. When the conditions became such that the ice front was melted back faster than it advanced, the final retreat of the ice began. While the edge of the ice was being melted back to the Valparaiso moraine, and while it stood in that position, the water which arose from its melting flowed off to the south. That from northern Illinois found its way by various valleys to the Mississippi, and thence to the sea. One line of drainage was down the Des Plaines Valley to the Illinois. When the ice retreated northeast of the Valparaiso moraine, the depression between the ice front, on the one side, and the moraine ridge, on the other, was flooded with glacial water, and a lake, marginal to the ice, came into existence. As the edge of the ice which formed one shore of the lake retreated northward, the lake enlarged. Its water rose until it reached a level about 60 feet above the present surface of Lake Michigan, when it overflowed to the west along the line of the present Des Plaines River Valley and through the Sag (Fig. 13; also Frontispiece and Plate II, p. 1).

The accumulation of water between the moraine and the ice was the beginning of what has been called Lake Chicago,[1] in some sense the

[1] Leverett, "The Pleistocene Features and Deposits of the Chicago Area," *Geol. and Nat. Hist. Surv., Bull. II* (1897), Chicago Academy of Sciences, p. 57.

ancestor of the present Lake Michigan. This lake is the third great factor to be considered in studying the geography of this region. The lines of drainage which developed into the present Des Plaines Valley and the Sag tributary to it have long been known as the Chicago outlet.

The Chicago outlet.—The general features of the outlet have been given. Near Lemont the valley is cut largely in rock, the limestone beds rising 40 to 60 feet above the valley bottom on either side. This valley probably is not preglacial, though it antedated the last glacial epoch. If so, it was partly filled with drift during that epoch. The top of the rock in the bluffs has about the same elevation as that of the waters of Lake Chicago at its highest stage.

At its maximum the discharge of water through this outlet must have been comparable to that now discharged through the Niagara River. Below Lemont the bed of the outlet declines 90 feet in 25 miles. Of this fall, 76 feet is made in less than 10 miles, between Romeo and the Joliet pool. The nature of the rock is such that it is not probable that a waterfall was established, but the high gradient must have caused strong rapids.

Stages in the history of Lake Chicago.—There were several more or less distinct stages in the history of Lake Chicago. During the first stage which has been recognized (the Glenwood stage, Fig. 13), its water seems to have stood about 60 feet higher than the level of Lake Michigan. This stage lasted for a considerable period of time, during which waves and shore currents did their appropriate work. Where the waves cut into the shores they developed cliffs; where they were depositing instead of eroding they made beaches, and the currents made spits of sand and gravel (Fig. 14). All this time the ice probably was melting back, so that the ice-shore of the lake was receding to the northeastward, and the area of the lake increasing.

Following this maximum stand of Lake Chicago, when its waters were 60 feet higher than those of Lake Michigan, there was a second stage during which the waters are thought to have been too low to discharge through the outlet to the west, or even to cover all of the Chicago plain. On this plain, so far as not covered with water, vegetation gained a foothold, and where marshy conditions prevailed, distinct deposits of peat were formed. This was the second stage of the lake. The reason for the lowering of the lake level at this stage is not known with certainty, but probably the ice had retreated so far to the north as to open an outlet in that direction, lower than that via the Des Plaines and Illinois.

Later, the water of the lake rose again, though not so high as before, covering the plain and burying the peat and other vegetal deposits under accumulations of sand and gravel. This rise of the lake was the beginning of its third stage (the Calumet stage, Fig. 16). The cause of the rise of the water may have been (1) an advance of the ice from the north, blocking the outlet to the north which had lowered the lake after the Glenwood stage, or (2) a rise of the land to the north, raising the outlet in that direction, and with it the level of the lake at the south end of the basin. As the waters rose, the discharge through the southwestern outlet was resumed. The third stage of the lake has left a record in a second line of beaches about 40 feet above the level of Lake Michigan, and about 20 feet below that of the first recorded stage.

The outflow lowered the outlet, and with this lowering the level of the lake was drawn down gradually. About 20 feet above the present lake its level remained nearly constant long enough to allow a third series of beaches to be developed. This may be called the fourth stage (the Tolleston stage, Fig. 17) of the lake.

Still later, an outlet was opened to the north, probably as the result of the recession of the ice. This outlet was lower than that by way of Lemont, and the level of the lake was drawn down sufficiently to cut off the flow via the outlet. When this was done, present conditions were inaugurated, and Lake Chicago gave place to Lake Michigan. Stated in other terms, Lake Chicago had developed into Lake Michigan.

THE BEACHES OF LAKE CHICAGO

1. THE UPPER OR GLENWOOD BEACH

The different levels at which the waters of Lake Chicago stood for any considerable length of time are marked by a series of well-defined shore-lines, whose ridges of beach sand and gravel have been mentioned (p. 3) as significant features of the Chicago plain. The positions of the various shore-lines are indicated on Plate II (p. 1), and in Figures 13, 16, and 17. As already stated, the water at first rose to a level about 60 feet above that of Lake Michigan, or 640 feet above sea-level, before it found an outlet, and at this level was formed the first and highest beach. To this Mr. Leverett has given the name Glenwood, from the village of Glenwood, on the Chicago & Eastern Illinois Railroad, four miles south of the Calumet River. At Glenwood the beach is especially

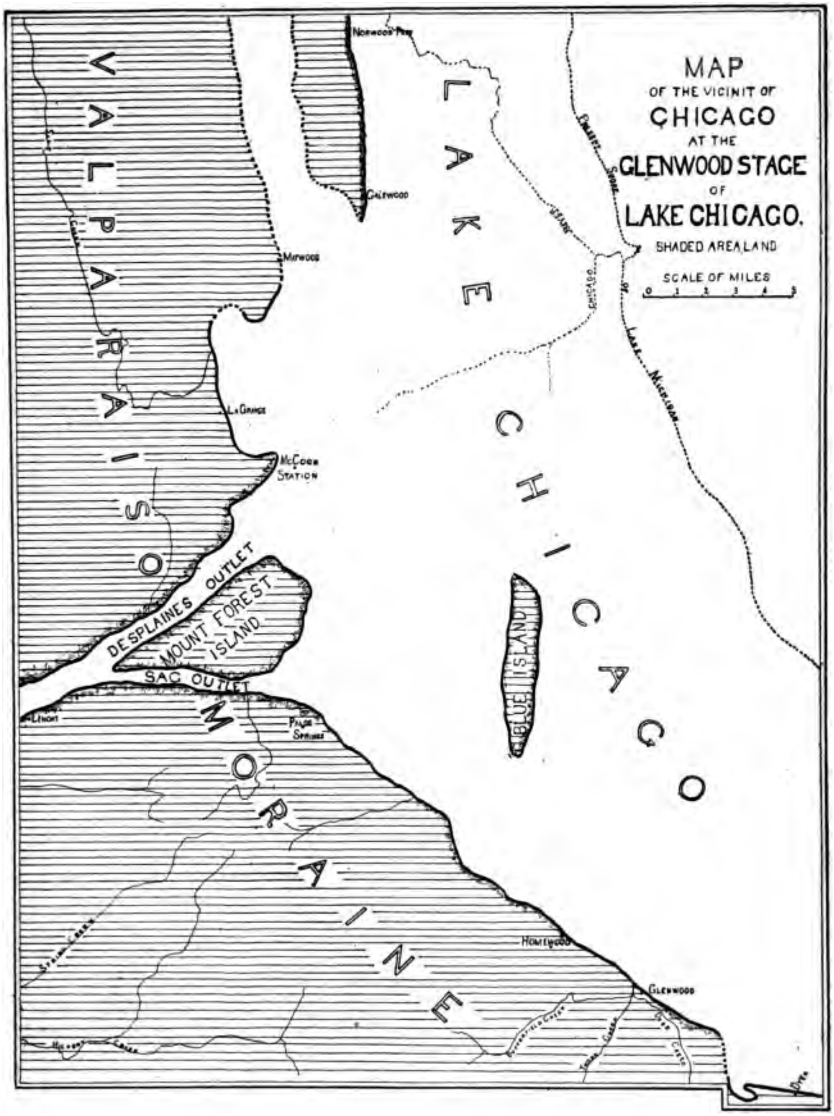

FIG. 13.—The vicinity of Chicago during the Glenwood stage of Lake Chicago. The area between the present shore and the shaded area was covered by water. The name Palos Springs has been changed to Palos Park.

well developed. The relations of land and water while the Glenwood beach was forming are shown on the map (Fig. 13).

The shore-line corresponding to the Glenwood beach extends an undetermined distance northward into Wisconsin, but is wanting between Winnetka and Waukegan, where the present shore is west of the position occupied by the shore of Lake Chicago when the Glenwood beach was formed.

The northern end of the Glenwood beach, so far as the environs of Chicago are concerned, lies on the crest of the present bluff near Winnetka. From the bluff at Winnetka this beach swings southwestward for several miles to Norwood Park (Plate II and Fig. 13) on the Wisconsin division of the Chicago & Northwestern Railway. Thence its course is southerly through Dunning County Farm and Galewood, to a point about a mile south of the Chicago, Milwaukee & St. Paul Railway. Extending northward between Galewood and Maywood there was a shallow bay two or three miles in width. From Maywood the beach swings southwestward and southward through La Grange to the line of the present Des Plaines Valley, near McCook Station, whence it makes for the outlet which, at this stage, was about three miles southwest of McCook. The outlet here was about a mile in width.

The head of the Sag outlet at the Glenwood stage was about two miles west of the village of Worth, and about half a mile in width. From the Sag, the Glenwood shore-line passes southeastward along the inner slope of the moraine, which rises now gently and now abruptly, from the plain. Passing about half a mile north of Homewood, on the Illinois Central Railroad, the shore extended southeastward through Glenwood, on the Chicago & Eastern Illinois Railroad.

Just southeast of Glenwood the beach deposits have been almost entirely removed by the erosion of Deer Creek, but half a mile farther on the beach is again seen, flanking the lakeward side of a sharp, narrow ridge of drift. Thence it runs eastward to Dyer, Indiana.

The Glenwood shore-line has certain features which deserve special mention.

The Oak Park spit.—From Norwood Park south to the Chicago, Milwaukee & St. Paul Railroad and beyond, the old shore-line lay along the east margin of a moderately high and slightly rolling tract, to the west of which there is a depressed area which was a shallow bay (Fig. 13), two or three miles in width, at the time the Glenwood beach was formed. In the western part of this low area the Des Plaines River has now cut

its channel. As there was little wave action in the bay its shore-lines are not clearly marked.

Across the debouchure of this bay the shore currents, moving southward toward the outlet under the influence of northeast winds, as along the west shore of Lake Michigan today, gradually built the shore drift into a long, narrow spit (Plate II and Fig. 14) diagonally across the mouth of the bay. This spit (or possibly a barrier beach) passes through Oak Park, terminating at Forest Home Cemetery, near the Des Plaines River. Its double curve is probably due to the combined action of the northeast winds and the current of outward flow from the bay. The former turned the spit southwestward, until the outlet of the bay was somewhat constricted, when the outward flow of water from the north became sufficiently strong to deflect the spit-building current again to the south.

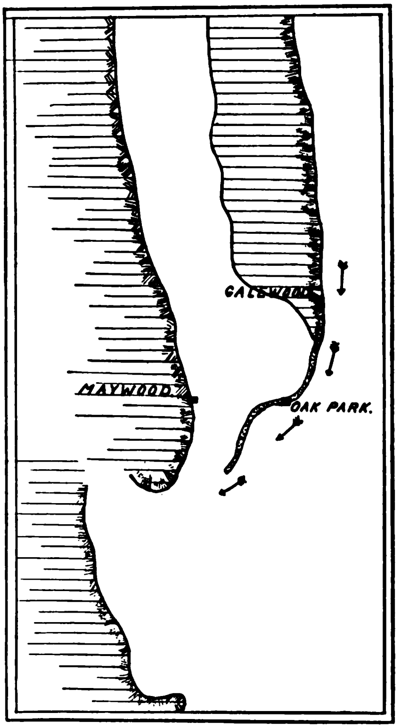

FIG. 14.—The Oak Park spit

The method of building a spit is readily explained. A current moved along the shore in the direction indicated by the arrows. While flowing on the shallow bottom near shore, the current carried along more or less sand and gravel. As it reached the point of land below Galewood, it continued across the bay in the general direction already assumed, instead of following the re-entrant of the shore. As it reached the deeper and more quiet waters opposite the mouth of the bay, its velocity was checked, the carrying power reduced, and the load dropped. More material was constantly brought forward, being carried out each time a little farther over the deposit already made. Thus the narrow submerged ridge of sand and gravel was extended out from the headland in the direction of the shore currents.

As the current flowed across the mouth of the bay, the sweep of the winds across the open water of the lake probably deflected it into the bay, and the spit received a like deflection. If the process of spit-building had continued until it reached the opposite shore of the bay, the bay would have been cut off completely, and the embankment would have formed a bar. If a bar is built up to the level of water of quiet weather, the waves of storms may throw up the material still higher, and the bar becomes the shore-line, with a lagoon shut in behind it.

Cliff and wave-cut terrace.—North of McCook the shore-line is marked by a wave-cut terrace and low cliff, cut in the glacial drift, rather than by a sandy beach.

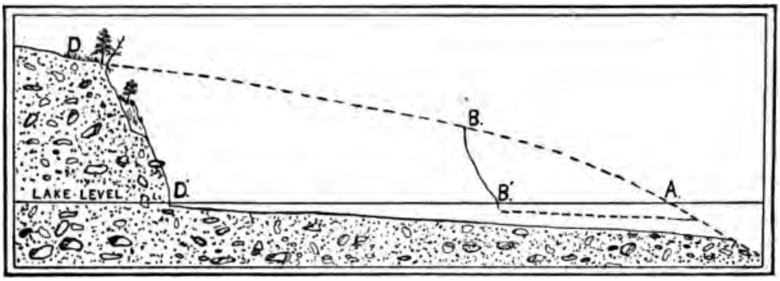

FIG. 15.—Diagrammatic section, illustrating the formation of a cliff and wave-cut terrace.

The method of formation of a cliff and wave-cut terrace is as follows: *DA* (Fig. 15) is a land surface sloping gently to a lake, the level of which is *D'A*, *A* being the original position of the shore. As the waves dash against the shore, the bank is more or less eroded, and the débris is either washed backward by the undertow and spread on the bottom, or carried along the shore by littoral currrents, and deposited wherever motion sufficient for its transportation fails. As the zone of greatest erosion is at the water's edge, extending a little above and below the level of quiet water, the shore is gradually cut backward as with a horizontal saw, the material above sliding and falling down when undercut, and being worked over and carried away by the waves and currents. Thus with a surface rising back from the shore, the shore grows higher as the water advances on the land, and becomes a cliff, while the bottom of the lake near shore slopes gently up to the water's edge, forming a wave-cut terrace. The horizontality of its landward margin, which also marks its junction

with the cliff, is the especial characteristic of the wave-cut terrace. It should be noted, however, that in the case of the ancient terraces from which the lake has withdrawn, their landward margins are locally rendered uneven by alluvial fans formed at the debouchures of ravines and gullies in the old lake cliff.

Dunes on the Glenwood beach.—A mile east of Homewood the beach is covered by dunes, or wind-blown sand, which originated later than the beach itself. In the field the shore gravels appear from beneath the dune sand and extend on toward Glenwood.

The Glenwood spit.—Southeast of Glenwood, and near the Illinois-Indiana line, there was a shallow bay (Fig. 13). The shore currents did not follow the shore of the bay, but, as in the case of the bay farther north near Galewood, they swept onward across the inlet, bearing the shore drift of sand and gravel with them. As the currents came into deeper water across the opening of the bay, they dropped their burdens of detritus, and gradually built it out into a great spit nearly two and one-quarter miles in length, almost completely shutting off the bay (Plate II, p. 1). The landward deflection of the detritus-bearing currents by easterly winds is well illustrated by the curved form of the spit. In quieter weather the current flow, and the consequent spit-building, was southeastward in the general direction of the shore-line, but during periods of heavy storms from the easterly quarter the currents were deflected into the bay, and the spit suffered a like deflection. During storms the distal part of the spit was probably washed away, and the material swept back into the bay in the form of a hook, and only with the return of more quiet weather was the extension of the spit in the original direction resumed. The structure as a whole is that of a great curved bar formed by a series of hooks extended, one from the other, with the same general front (Plate II). As this bar increased in height until it stood at or near the water level, it became the real shore-line, and was further heightened by accumulations of dune sand. This ridge has now a height of 15 feet above the plain to the north and east.

Duration of the Glenwood stage.—How long the waters stood at this upper level cannot be told, but it was long enough to accomplish considerable erosion of the outlet, and of the inner margin of the moraine-Most of the débris resulting from this shore erosion seems to have been sweptt hrough the outlet, instead of being deposited on the lake bottom.

Changes of water level.—The level of the lake probably was not constant during the Glenwood stage. The outlet was being cut down

continuously, and the level of the water in the lake correspondingly lowered. How much it had been lowered before the next succeeding stage of the lake was inaugurated is unknown, but there is some reason for thinking that it may have lowered about 20 feet. As the water level became lower, the level of wave-cutting was lowered correspondingly, and the cutting edge of the waves was felt at all levels successively from the highest stand of the lake (640 feet) to the lowest.

Life.—No satisfactory evidence of life has been found in the waters of the lake at the Glenwood stage. This is as would be expected in waters mostly derived from the melting of the great ice-sheet.

Blue Island.—Within the area of the Chicago plain shown on Plate II, and within the area of that part of Lake Chicago shown in Figures 1 and 13, the only emerging land was Blue Island, the ridge of drift already mentioned (p. 3). That this is a ridge of drift, and not of rock covered with a mantle of drift, is shown by well borings. The well at Morgan Park Water Works shows 76 feet of drift overlying the rock, while the well at the Blue Island smelter, on the flat about one and a fourth miles to the south, shows 40 feet of drift over the rock. The difference in elevation between the two points is such as to show that the surface of the rock has almost the same level under the ridge as under the flat.

There seems to be no assignable reason why excessive deposition should have occurred at this place. It is probable that, as left by the ice, this elevation of drift spread out to the east, north, and south somewhat more than now, with more gentle slopes, such as it now has on the west. If this be true, it originally formed a broader and less abrupt swell than now.

At the Glenwood stage of the lake this drift ridge was an island rising 10 to 35 feet above the waters of Lake Chicago. On its eastern side the waters developed a cliff, and the débris resulting from the erosion was carried out some slight distance from the shore. The currents toward the outlet from the east and southeast appear to have been divided by the ridge, one part of the water sweeping about the north end, and the other part about the south. These currents gathered up the débris which the waves developed, and swept it out to the leeward of the island in a pair of spits, one at the north end and one at the south (Fig. 5). That at the north is best seen at the Catholic Cemetery at Ste. Maria on the Chicago & Grand Trunk Railway. It may be that the accumulations of bowlders at the north end of the Blue Island Ridge are

a remnant from this erosion, being the coarse materials which the waves and currents were not able to carry away.

The deposits of sand and gravel seen just east of the till ridge at Morgan Park, at Washington Heights, and elsewhere probably were built in the form of barrier ridges by the action of the waves and currents. The beach gravels along the west side of the island are buried beneath an accumulation of dune sand which was blown up later, when the sandy flat to the west emerged from the waters. This well-defined dune sand deposit gives evidence of prevailing west and southwest winds, as at present.

Interval of emergence.—After the Glenwood beach was formed, a northern outlet for the lake seems to have been opened, and its level was lowered until the waters of the lake receded to or beyond the present shore-line of Lake Michigan. The opening of the northern outlet was probably due to a recession of the ice-sheet beyond some valley lower than the Chicago outlet. As before stated, the evidence of the emergence of the Chicago plain at this time is found in a bed of peat beneath the deposits of the succeeding stage, showing that the waters must have withdrawn from the plain for a time sufficiently long to allow vegetation to grow and accumulate before the area was re-submerged and the later deposits laid down. These deposits were well seen some years ago in a section on the campus of Northwestern University, Evanston. Further evidence concerning this interval of emergence is desired. Recent investigation has not discovered new data bearing on the subject, which remains as set forth by Dr. Andrews years ago, and more recently by Mr. Leverett.

2. THE CALUMET BEACH

Following the period of emergence, the waters of Lake Chicago again rose and flooded the Chicago plain. This re-submergence may have been due to a return of the glacier ice to the northern end of the basin, blocking the outlet which had been opened to the north, or to a rise of the land in that direction, lifting the outlet and causing the water in the lake to rise. The height to which the water rose in the second submergence of the Chicago plain is marked by the second or Calumet beach, about 35 to 40 feet above the present lake, and about 20 feet below the beach of the Glenwood stage. It is the rise to this level, and not higher, which suggests that the water of the Glenwood stage had been drawn down about 20 feet by the lowering of the outlet (p. 34).

Like the older beach, this lower and younger one has its correlative in Wisconsin. It has been recognized 25 miles north of Milwaukee, but from this latitude southward to a point between Racine and Kenosha, a distance of more than 50 miles, it has been cut away by the advance of the lake on the land in later times. From the Wisconsin line southward to the Chicago River the second beach is closely associated with the first, wherever the first remains.

South of the North Branch of the Chicago River the Calumet beach is seen in good development at Jefferson Park (Fig. 16). Thence it runs through Cragin, to Austin and Riverside. Through this distance of 12 miles there is a continuous well-developed beach ridge of sand and gravel.

At this stage of the lake the drainage of the region northwest of its border, along the line of the Des Plaines River, and probably along the line of Salt Creek, entered the lake between Riverside and the rock elevation at Lyons.

From Riverside to the outlet, the head of which at this stage was at Summit, the Calumet shore-line is not well defined.

At the Calumet stage of the lake the Mount Forest and Blue Island islands of the Glenwood stage were no longer separate, for the plain between them was above water. These islands of the Glenwood stage, and the area between them, now formed one large island between the two outlets. Sag Station marks its western extremity, Summit the northern, and Blue Island village the southeastern.

From Summit the shore-line of the Calumet stage swung in a broad curve southeastward about the north end of the Blue Island Ridge, through Washington Heights. Throughout this distance of eleven and one-half miles the Calumet beach is marked by a continuous, well-developed ridge of sand and gravel, 5 to 10 feet high and 50 to 100 yards wide.

The head of the Sag outlet at this stage may be considered as lying between the south end of the Blue Island ridge and the inner margin of the moraine 3 miles farther southwest. If this be considered the head of the outlet, the water passing through it was divided into two currents by a low body of land known as Lane's Island. The area of this island was submerged in the Glenwood stage, but the lower water of the Calumet stage left the crest of the low ridge exposed. The village of Worth, on the Wabash Railway, stands at its western end.

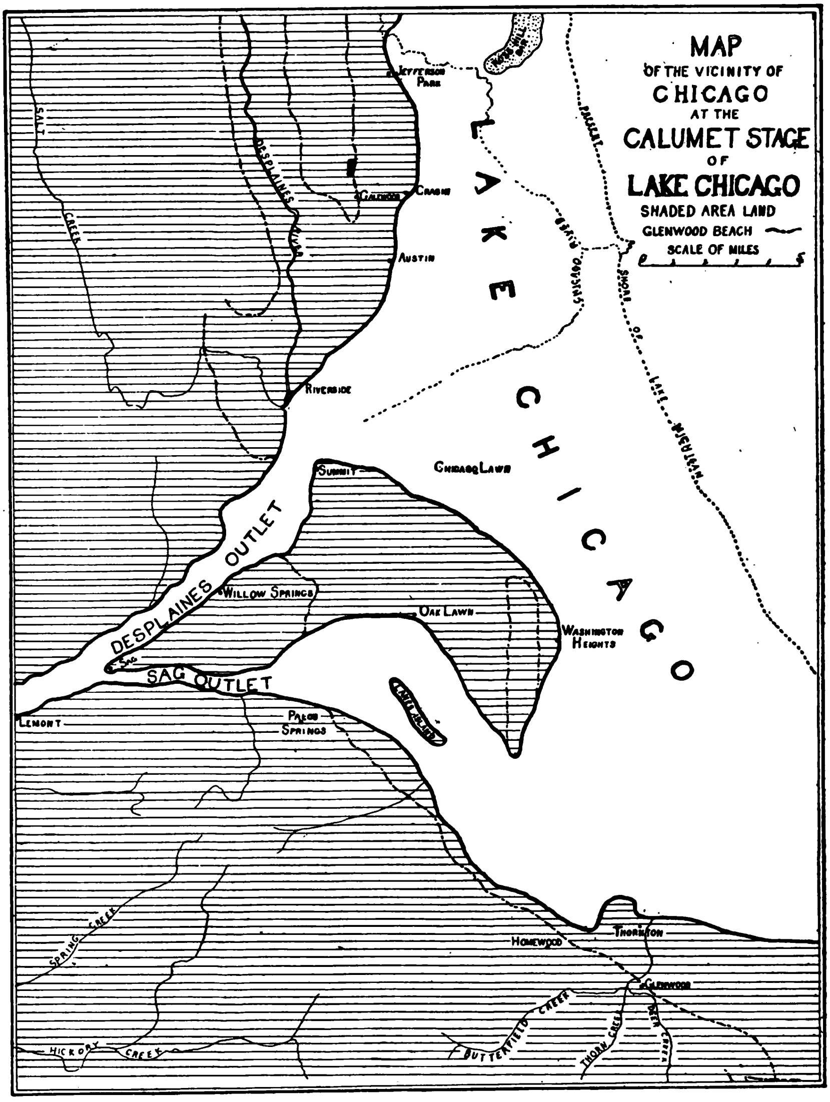

FIG. 16.—The Calumet stage of Lake Chicago. The unshaded area west of the present lake was covered by water. The figure also shows the position of the Glenwood beach. Compare Fig. 13. Palos Springs = Palos Park.

From the south side of the Sag outlet to the rock elevation at Thornton the Calumet shore-line was almost parallel to that of the preceding stage, and about half a mile inside it. The line is here marked by a continuous ridge of beach sand and gravel. After swinging to the northward about the Thornton elevation, this ridge continues eastward into Indiana.

Between Homewood and Thornton there is a considerable deposit of dune sand, in hillocks 20 to 30 feet in height, now well covered by vegetation. These dunes overlie part of the beach deposits of the Glenwood stage. The eolian sand which overlies the Glenwood beach may have originated at any time subsequent to the formation of that beach; but that which overlies the Calumet beach must belong to the Calumet or to some later stage. There is also much dune sand associated with the Calumet beach east of Thornton.

Rose Hill bar.—From the Calumet beach, north of Chicago, there extended into the Chicago embayment at this stage a conspicuous bar (Plate II). Its northern end is found at the present lake shore between Wilmette and Evanston. Its connection with the old shore-line has been cut away by the advance of the lake on the land. It runs southward through the western part of Evanston, and on it, near its southern extremity, is Rose Hill Cemetery. It is beneath this bar that the peat deposits which give the evidence of an interval of emergence between this and the Glenwood stage of the lake were found.

Evidence of life in the lacustrine deposits of the Calumet stage.—In connection with the evidence of a withdrawal of the water from the Chicago plain at the close of the Glenwood stage, and its consequent submergence by the waters of the Calumet stage, the finding of evidences of life in these lake deposits is of especial interest. The occurrence of shells in the Calumet beach deposits at Summit and near New Buffalo, Michigan, has been reported, but no definite information has been secured concerning them. The only place where definite evidence of life has been found about Chicago is at the farm of Mr. J. H. Welch, about one and a half miles southwest of Chicago Lawn. The Calumet shore-line was spoken of as being marked by a well-developed ridge of sand and gravel swinging in a broad curve from Summit southeastward about the north end of the Blue Island Ridge. In Mr. Welch's field, just northwest of the point where this ridge is cut by the Belt Railway, there have been found numerous molluscan shells and one specimen of coral. An examination of these specimens showed them, without exception,

to be of marine species, whose present range is between Prince Edward Island and the West Indies.[1] With the specimens which could be identified there were many fragments so much worn and so thoroughly perforated as not to permit of identification. The character of the evidence which these shells seem to afford is of such a radical nature as to excite great interest, and conclusions must be drawn with extreme caution.

The question is, Were the shells left in their present position by natural agencies? To say that they reached their present position by natural means is to say that the waters of Lake Chicago at the Calumet stage were salt. This would seemingly require the subsidence of this and surrounding areas to such a level as would allow the incursion of the sea over this part of the interior of the continent, and their subsequent elevation to the present altitude of 620 feet above tide, within very recent geological time.

It is true that this is not the first or only suggestion of such a subsidence and marine incursion. Dr. R. W. Ells,[2] of the Geological Survey of Canada, has brought forward evidence to show that the ocean extended westward throughout the upper Ottawa basin in post-glacial time, leaving marine deposits which are now 1,000 feet above the sea-level. Dr. Bell[3] also records the presence of marine deposits north of Lake Superior, along the Kenogami River, at an elevation of 450 feet above sea-level. It is not unreasonable that subsidence of the area about Chicago should have occurred as a part of the more general subsidence of which these marine deposits to the north and northeast seem to be evidence. A recent

[1] The species as identified by Mr. Frank C. Baker, of the Chicago Academy of Sciences, are as follows:

PELECYPODS: *Ostrea virginica* Gmelin, ranging at present from Prince Edward Island to the West Indies. These specimens are very largely perforated by boring sponges. *Arca transversa* Linne, ranging from Cape Cod to Key West. *Venus cancellata* Linne, ranging from Cape Hatteras to Trinidad. *Venus mercinarius* (?) Linne. *Pecten* (Sp.?), possibly *Chlamys irradians* Linne, a fragment. *Gnathodon cuneatus* Gray, Gulf of Mexico.

GASTROPODS: *Fulgar perversus* Linne, ranging from Cape Hatteras to Cuba. *Cerithium* (Sp.?), apical whorls only found. *Cerithiopsis* (Sp.?), apical whorls only found.

CORAL: *Oculina robusta* Pourtales, West Indies.

[2] Dr. R. W. Ells, "Sands and Clays of the Ottawa Basin," *Bull. Geol. Soc. Am.*, Vol. IX (February, 1898), pp. 211–22.

[3] *Report of Progress, Canadian Geol. Surv.*, Vol. VI (1895), p. 340.

statement by the Geological Survey of Canada indicates a maximum submergence of about 800 feet in Eastern Canada since the retreat of the last ice.

Along the lake shore there are certain plants,[1] long regarded as seashore plants, and these, together with the existence of a *Mysis*, a species of marine crustacean, in the lake, have been taken as evidence that salt water has at some time since the glacial period existed where Lake Michigan now is.[2]

The presence of the fossils mentioned above conceivably may be accounted for by artificial introduction. They may have been thrown there by white men, or introduced in a fertilizer used on the soil. The well-known trading of the Indians of the northern interior with the south and east coast might account for their having been left here before the coming of white men. They might have been left on the beach of Lake Chicago by the Indians of that time, and have been water-worn and buried by the waves of its shore.

It should be noted that the physical relations indicate that the Calumet beach marks the border of a lake which seems to have stood sufficiently above sea-level to maintain a strong current through its outlet, which seems incompatible with the occurrence of marine life in its waters.

On the other hand, the water-worn and fragmental condition of a large part of the marine shells found on the Calumet beach, the thorough perforation of many specimens as by sea-borers, the occurrence of very delicate, tiny shells in the sand filling the coils of the larger gastropod shells, together with the statement of Mr. Welch that he himself cleared the ridge of its native trees and underbrush, broke the sod, and has lived there for nearly thirty years, that he never used any fertilizer containing shells, that the only evidence of Indian residence he has ever found was a

[1] These plants are *Triglochin maritima* (arrow grass); *Salsola kali* (Russian thistle); *Cakile americana* (sea rocket); *Prunus maritima* (beach plum); *Lathyrus maritimus* (beach pea); *Euphorbia poligonifolia* (seaside spurge).

This list of plants is kindly furnished by Dr. H. C. Cowles, of the University of Chicago. It should be stated, however, that Dr. Cowles gives little credence to them as evidence of marine conditions here, rather considering it as begging the question to regard plants with such a wide range along the interior lake shores as strictly seashore plants.

[2] Wm. K. Higley and Charles S. Raddin, "The Flora of Cook County, Illinois, and a Part of Lake County, Indiana," *Bull. Chicago Acad. Sci.*, Vol. II (1891), No. 1, p. 15.

single arrowhead, that he has plowed up and gathered the shells ever since the ground was broken—all these facts are against the idea of an artificial introduction of the shells, and favor the idea of deposition *in situ* by marine waters. The southern range of all the species found would also seem to preclude the idea of their introduction from the north or northeast, for the shells found by Drs. Bell and Ells are all of arctic species. If the shells be evidence of an incursion of the sea, their occurrence, so far as known on this second, or Calumet, beach only, would indicate this stage (or a part of it) as the time of the incursion of the sea, and the southern range of all these species at the present day would indicate that the incursion was not from the northeast through the St. Lawrence embayment, but from the south, through a Mississippi embayment.

In view of these apparently conflicting considerations, final judgment concerning the interpretation of the shells must be suspended until further evidence is forthcoming. It certainly is not safe to conclude that the sea stood over this area in post-glacial time.

3. THE THIRD OR TOLLESTON BEACH

Following the Calumet stage of the lake there was a stage during which the waters stood at a level but 20 feet above the present lake. The lowering of the lake from the preceding stage may have been due to a reopening of the outlet to the north, or to a rapid cutting down of the outlet. The change of level may have been less sudden than the position of the two shore-lines might lead us to infer.

At this stage of the lake a third beach was developed, called the Tolleston beach, from the village of Tolleston in northwestern Indiana. The relations of land and water at this stage, so far as the vicinity of Chicago is concerned, are shown in Figure 17.

Remnants of a terrace at a level corresponding to this shore-line have been seen at various points in Wisconsin. Such a terrace has been seen north of Milwaukee, but between Milwaukee and Kenosha it has been destroyed by the encroaching of the lake on the land. From Kenosha to Waukegan it is well developed, and is followed closely by the line of the Chicago & Northwestern Railway. Thence southward to Evanston the advancing shore of the lake has removed all trace of this beach. At Evanston, on the grounds of Northwestern University, this beach appears at the present shore-line, and runs southward along

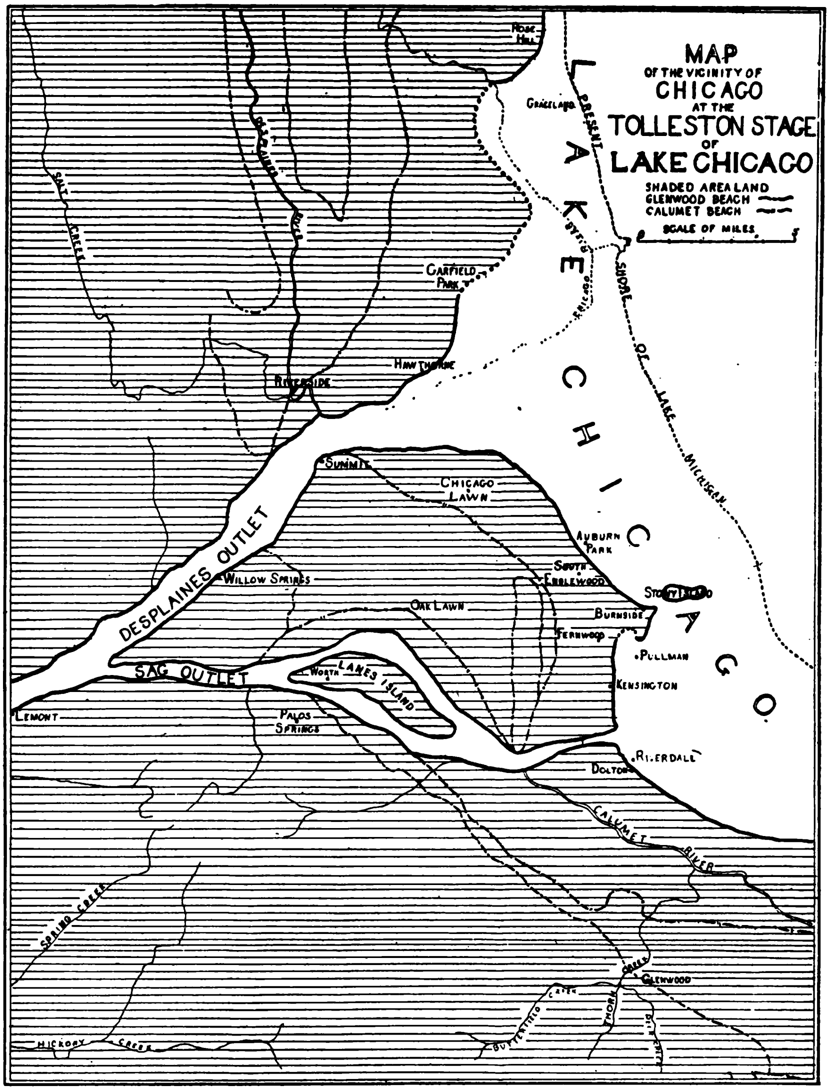

FIG. 17.—The relations of land and water about Chicago at the Tolleston stage of Lake Chicago. Shaded areas, land. Compare with Fig. 16.

the eastern border of the Rose Hill bar formed at the preceding stage of the lake (Plate II, p. 1).

The low area to the west of Rose Hill probably was flooded for a time at this stage, but the shore-line from Rose Hill to near Hawthorne is poorly marked. Traces of it are seen near Milwaukee Avenue and North Avenue, at the rock elevation near the intersection of Chicago and Western avenues, and southwestward from the corner of Douglas and Central Park boulevards. From the rock elevation at Hawthorne, however, which marks the north side of the head of the outlet at this stage, to the Des Plaines River a mile north of Summit, the shore of the Tolleston stage of the lake is well defined by a sandy beach.

From Summit toward Willow Springs the shore of the outlet at this stage is marked by the 15- to 20-foot drift bluff now followed by Archer road. From Summit eastward the south shore of the outlet is marked by a low bluff. From one-half mile west of the corner of Western Avenue and Garfield Boulevard the shore-line is marked by a strong ridge of sand and gravel which swings in a broad curve southeastward through Auburn Park to South Englewood.

In the earlier part of the Tolleston stage the shore-line seems to have swung off to the south and southeastward from near the intersection of South Halsted and Eighty-seventh streets, and, passing through Fernwood at Stewart Avenue and One Hundred and Third Street, turned southward along the drift cliff, passing through Kensington to the Calumet River at Riverdale. The Sag outlet, probably not a very active line of discharge at this stage, seems to have occupied the present line of the Calumet River (reversed) between Riverdale and Blue Island. The head of the outlet was narrow, and seems soon to have been blocked by a bar formed from material borne by the shore currents southward along the Kensington cliff.

West of Blue Island the channel was divided as before by Lane's Island, now considerably enlarged by the lowering of the surrounding waters.

From Dolton, southeastward into Indiana, the shore-line is marked by extensive deposits of beach sand and gravel, now much covered by accumulations of dune sand.

From the position of Rose Hill Cemetery, where the Rose Hill bar was deflected to the southwest, the shore currents continued southward, depositing their material in a great reef over most of that part of the North Side of the city of Chicago which lies between the North Branch

of the Chicago River and the present shore of Lake Michigan (Fig. 5, p. 10). The slight elevation which this deposit made is traversed by North Clark Street, and about midway of its length is Graceland Cemetery.

As this broad, reeflike deposit extended southward and increased in height, it finally became the shore-line, cutting off whatever bay lay to the west. Up to recent times this reef was traceable to a point about a mile south of Lincoln Park. It is said to have been nearly continuous through the city of Chicago, but it is now scarcely recognizable for a distance of 5 or 6 miles to the southward. In this stretch, grading has destroyed it. Twenty-five years ago it was traceable southward from Groveland Park, at Cottage Grove Avenue and Thirty-fourth Street, and southwestward through the northwestern part of Washington Park, Englewood, and Auburn Park, to South Englewood, where it unites with the shore-line just described. Traces of it north of Fiftieth Street are now very meager.

This broad reef appears to have been built southwestward as a series of overlapping hooks which were turned into the bay at the west in the manner already described (p. 33).

The advance of the reef constricted the channel of free flow toward the outlet, and the drainage in that direction was shifted more and more to the south. At the same time the lowering of the lake level seems to have diminished the outflow, so that the current was feeble, and finally destroyed, and the bar was completed across the bay to the farther shore at South Englewood (Fig. 17). This is the most notable instance within the area studied of the process of cutting off embayments, and the consequent simplification of the shore-line. The southern part of the area behind (west of) this bar eventually drained out to the eastward through the depression now occupied by the Auburn Park lagoon, and the establishment of the Chicago River probably drained the remainder.

It probably was while this reef was being built, and the overflow to the west diminished, that the present outlet of the lake to the north was being established. As the outflow to the north increased, that via Summit diminished.

At the Tolleston stage of the lake Stony Island had begun to emerge as a reef and then as an island (Fig. 17), and its position gave it a controlling influence on the currents. Under its protection the currents shifted southward by the extension of the reef already referred to, began to work upon the gentle drift slope of the land along the west shore of the lake,

and a low terrace, surmounted by a sandy beach, was developed from South Englewood, through Burnside to the lee of Stony Island. These southeasterly currents were here met by the westward currents about Stony Island, and turned abruptly southwestward toward the present site of Pullman. As a result of the reefs made by these currents, the shore-line was shifted eastward, and its original position through Fernwood was abandoned.

Stony Island.—Stony Island is an elevation of rock. Its strata have quaquaversal or periclinal dips, i.e., the strata, on all sides of the dome, dip outward (Fig. 6). The angle of dip ranges from 30° to 42°. At first thought the "island" appears not to be an erosion remnant, but due to a local elevation of the rock strata. Gentle undulations of the rock beds are seen at other exposures, but none so abrupt as this. No very satisfactory evidence is at hand by which the date of the uplift which deformed the beds can be fixed. If it preceded the later part of the erosion which affected the limestone before the glacial period, the erosion remnant (that is, the island) happened to correspond in position with the center of the uplift. There is evidence in the rock itself that its deformation took place while the layers which are now exposed were under great weight. If this is so, the great weight probably was the weight of other beds since eroded away.

Large island to the west of Stony Island.—The large island of the Calumet stage, made by the union of Blue Island and the Mount Forest Island of the Glenwood stage, was still larger during the Tolleston stage (Fig. 17. Compare Figs. 13 and 16). This was the necessary result of the lowering of the waters of the lake.

Evidences of life at the Tolleston stage.—In striking contrast with the Glenwood and Calumet beaches, the Tolleston beach contains abundant traces of life closely related to the life of Lake Michigan, if not identical with it. This probably means that the waters of this stage were warmer than those of the earlier stages.

Changes in topography effected by Lake Chicago.—Aside from the phenomena of the shore-lines set forth in the preceding pages, certain changes in the topography of the Chicago plain were effected by the waters of Lake Chicago.

First and last, the level of Lake Chicago fluctuated from its maximum, about 640 feet above tide to the present level of Lake Michigan, 581 feet. The shore was at some time or other at all levels between these extremes, and the horizontal cutting of its waves therefore affected all

parts of the Chicago plain. By this cutting, the inequalities of the surface of the drift of the plain, as left by the ice, were almost entirely obliterated, changing a plain that was at least slightly undulating to one which is exceptionally flat. The Blue Island Ridge was doubtless the highest drift swell, and was not entirely removed, though probably much narrowed by the waves. During the Glenwood stage of the lake, the Valparaiso moraine was cut back a little to its present position, leaving the lake plain with a border which is, in many places, abrupt. Most of the débris resulting from the erosion of the shores of the lake was carried out through the outlet, though some of it is seen in the beaches, and some of it was spread, as stratified drift, over certain parts of the plain.

RECENT CHANGES

Lake Michigan beach.—With the final diversion of the waters of the lake from the outlet to the north, the history of Lake Chicago may be considered as passing into the history of Lake Michigan, so that the series of beaches and bars lying between the Tolleston shore-line of Lake Chicago and the present shore of Lake Michigan mark the closing stages of the history of Lake Chicago and the earliest stages of Lake Michigan. During this stage that part of the Chicago plain which was still submerged was being built up by deposits of sand and gravel brought to the head of the lake by the southward drift of the littoral currents. In the northern part of the city, as far south as Lincoln Park, there is a close-set series of sand and gravel ridges 10 to 15 feet high (now partially destroyed) between the Tolleston beach and the present shore of the lake. Many of these ridges are capped with a little dune sand. Southward from Thirty-fifth Street (Plate II) the deposits of this stage covered a considerable area. Northeast and east of Washington Park there was a series of 10 to 12 low ridges, now largely destroyed by grading. These were built as subaqueous ridges by drift from the north. They have a roughly parallel direction, and vary in length from 1 to 6 miles, running out into the sandy plain. Their southern ends are (or were), as a rule, turned slightly to the west, giving them the form of a shallow hook. The longest and most prominent of these ridges was that passing through the campus of the University of Chicago, where its structure was well seen before destroyed by grading. It continues southward through the western part of Oakwoods Cemetery, terminating a mile north of Burnside.

The basin of Lake Calumet probably is due, in part, to the influence of Stony Island, which deflected the currents about its eastern end, whence they continued southward, depositing sand and gravel along their course, and leaving the area of the shallow lake unfilled. Like ridges inclosed other shallow lakes such as Hyde Lake, Wolf Lake (Plate II), and Lake George (Fig. 22), as well as adjacent marshy areas.

Between these lakes and the Tolleston beach to the south is a remarkable series of parallel ridges, so closely set that they cannot all be separately represented on the map. Including those indicated on the map as belonging to the Tolleston stage, there are, from Hammond north to the south end of Lake George, ninety of these ridges, ranging from 3 to 10 feet in height. They are separated, in many cases, by narrow, marshy belts. The ridges running southward between these lakes and marshes break up into several narrow ridges, and curve to the eastward. They are composed of sand with little gravel and, taken together, have the form of a great depositional terrace. This extensive filling, together with a slight lowering of the water level, brought the lake shore to its present position. The drift of the sand at the head of the lake and its accumulation there is still in progress.

Shore erosion.—The opposite phase of lake-shore work, wave erosion, is also well shown near the city. From Evanston northward the waves of the lake are cutting into the bluffs and driving the shore-line farther and farther west (Figs. 15 and 17). Locally and very recently this advance of the water on the land has been stayed by various human devices, but the process by which cliffs and wave-cut terraces are developed is still clearly shown. Figure 15 illustrates the changes which have taken place where the shore of the lake is a bluff. The surface, as left by the ice, occupied some such position as that indicated by the line AD. The waves have cut back to D'. The cliff is bordered by a submerged, wave-cut terrace to the right of D'.

The material eroded by the waves from the bluffs has been shifted southward. The fact of this southerly transportation may be seen in the accumulations of sand on the north sides of most piers extending into the lake, and in the spits wrapping around the ends of these piers from north to south below the water surface.

As at earlier stages in the history of the lake, so now, bars are forming across river mouths, and must be removed repeatedly by dredging to keep the harbors open. Before the improvement of the present harbor at Chicago there was a bar across the outlet of the Chicago River, which

shifted the debouchure southward nearly half a mile from its present position (Fig. 20), opposite the foot of Madison Street. The Calumet River has undergone similar changes (Figs. 21 and 22). That part of the stream east of Hegewisch (Fig. 22) has been reversed by the dredging of a channel from Hegewisch to the outlet of Lake Calumet.

FIG. 18.—Cliff on the shore near Glencoe. There is a narrow beach at the base of the cliff. (Harms.)

Some years ago Dr. Edmund Andrews[1] discussed the present beach of Lake Michigan, and compared its strength with that of the beaches of Lake Chicago. His paper is now out of print, but the computations have been reproduced and supplemented by Mr. Leverett in his paper already referred to. The computations were made for the purpose of obtaining a measure of post-glacial time, and were based on the rate of shore erosion to the north, the rate of littoral transportation to the south, and the amount of filling already accomplished since the withdrawal of the ice. While there are many unknown and undeterminable

[1] Edmund Andrews, M.D., "The North American Lakes Considered as Chronometers of Post-Glacial Time," *Trans. Chi. Acad. Sci.*, Vol. II (1870), pp. 1–23.

Fig. 19.—Cliff on the lake in southern Wisconsin. There is no beach in this case, and the waves are still cutting in on the base of the cliff, causing it to recede. The drift in the upper part of the cliff is stratified.

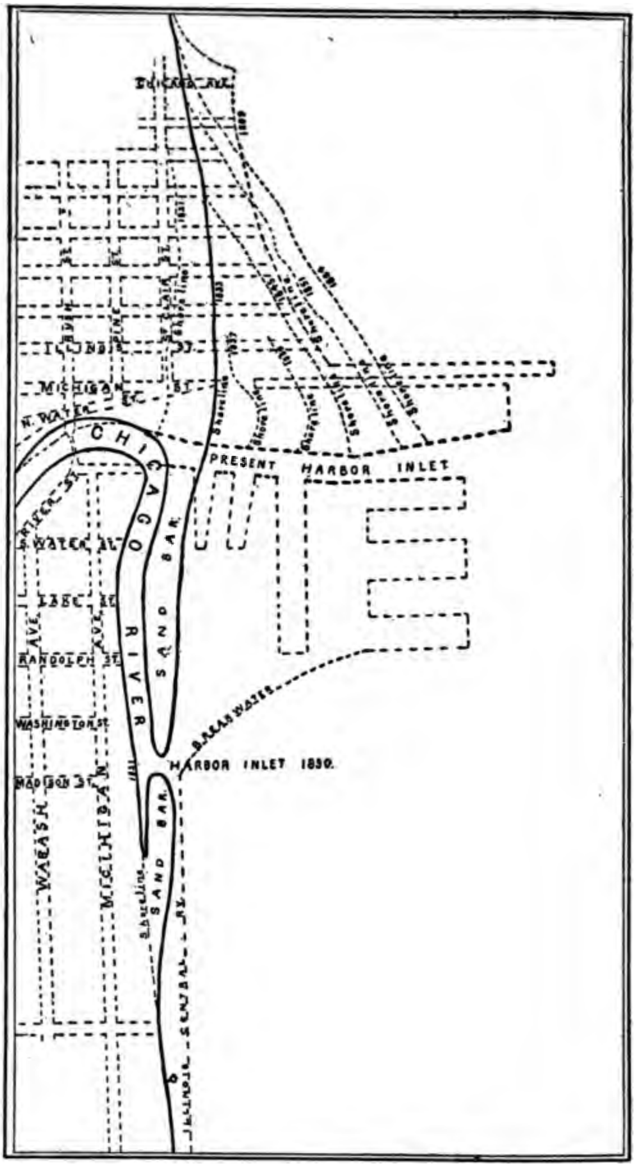

FIG. 20.—Figure illustrating changes in the position of the debouchure of the Chicago River. The position of the outlets in 1830, and at the present time, are shown, and also the position of the sand-bar which caused the deflection. (Adapted from map of Col. T. J. Crane, U.S. Corps of Engineers.)

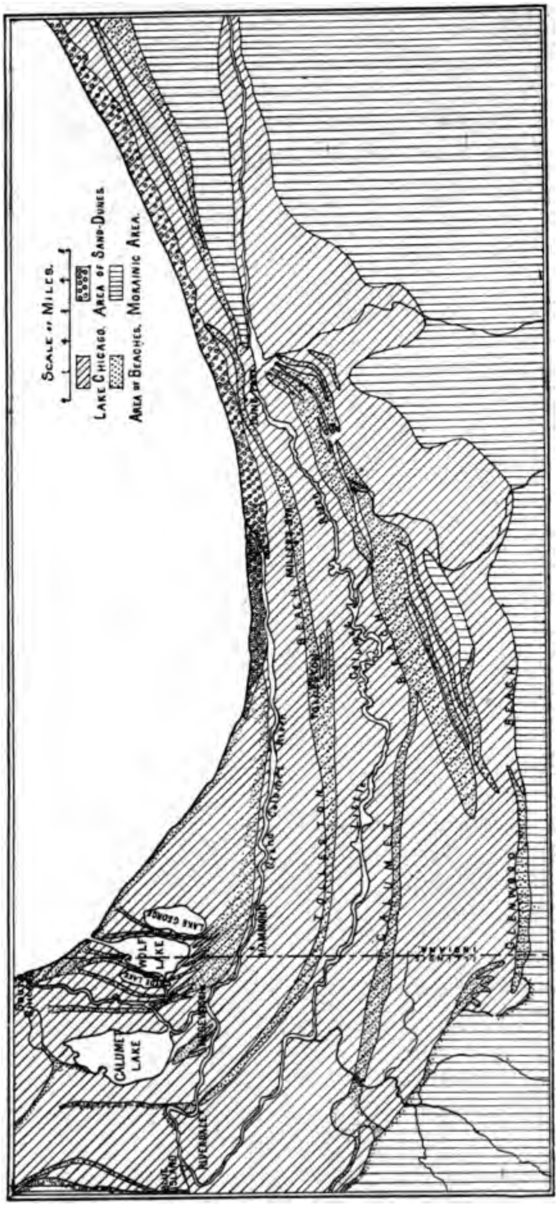

FIG. 21.—The Calumet River in the early days of Lake Michigan. The course of the stream is controlled by the beach ridges

the land. The advance is recorded in the cliffs along the north shore, extending north far beyond the boundary of Illinois. The extent of the land cut away by the waves is not known, but it is considerable.

As the waves advanced on the land by cutting away the drift, the bowlders and stones too large for the waves to transport were left near the foot of the cliff. The gravel (small stones) was shifted out somewhat

FIG. 23.—Dune near Dune Park. (Cowles)

from the shore, but not out into deep water. The sand, more easily transported, was shifted more extensively than the gravel, some of it being carried out from shore, and some of it shifted along the beach to the southward. The mud, the finest part of the drift, is made up of particles of rock so small that they are readily suspended in agitated waters, and were floated out considerable distances into the lake, where they settled to the bottom. In storms the lake is roily for considerable distances out from the shore, the distance being greater when the waves are strong and less when they are feeble.

On the west shore of the lake, there is a distinct southward movement of the waters in the form of shore currents. These shore currents are, as a rule, not pronounced enough to be seen, but their existence is readily demonstrated by the southward drift of sand, as shown at most of the many piers built out into the lake along the north shore, for the sand is lodged in quantity against their north sides. Since there is no corresponding accumulation on their south sides, it is clear that the sand travels southward along shore and is stopped by the piers. Many of the piers were, indeed, built to arrest the sand in its southward journey. Once it is lodged against them, the incoming waves expend their force on the sand, instead of cutting farther into the cliffs, as they did before the piers were built.

This southward drift of the sand went on, without let or hindrance, for thousands of years before the region was settled, and the sand was deposited in large quantities about the head of the lake. Considerable areas of land were reclaimed from the lake in this way. While the water gained on the land along the north shore, the land gained on the water at the south end of the lake.

Dune-making.—Whenever the sand of the beaches, built above the normal level of the lake by strong waves, became dry, winds from the lake blew the sand inland. Sand thus blown is not distributed evenly, but is lodged about any obstacle which is found in its path. As the brisk wind which is carrying sand passes an obstructing object, such as a tree, a shrub, or even a tuft of grass, its current is checked or stopped, and in the quieter area in the lee of the obstruction some of the sand is dropped, much as drifting snow would be. A little drift of sand accumulating in such a position is the beginning of a dune. Hundreds of miniature dunes may be seen along the shore at the present time, and in some places in among the larger active dunes. After a drift of sand attains appreciable size, it itself becomes an obstruction against and beyond which more sand lodges. Thus the dune grows, somewhat as a snow bank does, and under favorable conditions may attain great size (Fig. 23).

The formation of sand dunes by the blowing up of the sand from the beach has been going on, perhaps, since the birth of Lake Chicago; but the most striking results have been accomplished since the shore of the lake reached approximately its present position. The first dunes about the head of the lake doubtless were developed near the shore of Lake Chicago. This was far south of the head of the present lake and

some 60 feet higher. Dunes are found in Illinois and in Indiana at various points along the shores of this earliest lake, but they are not very large or conspicuous. Most of them are now well covered with vegetation.

As the level of the lake became lower, its shore approaching more nearly the present shore, dunes were formed at the various places where

FIG. 24.—A dune in process of destruction. Sand has been blown away, except where held by the roots of the trees. (Cowles.) See also Fig. 27.

its border remained for any considerable period of time. Few of these dunes, however, attained great size, and it was not until the lake had been lowered nearly to its present level that it appears to have stood long enough in one position to allow great dunes to be developed near its border.

The movement of dunes.—Dunes migrate. That is, the wind blows sand from the slope which it strikes, up over the top of the dune, and it is deposited on the other side. Thus, by a gradual shifting of the sand

from the windward to the leeward side, the site of the dune is shifted. This is at least a part of the explanation of the wide belt of dunes about the head of the lake. The dunes far inland doubtless were moved from their original position by the gradual transfer of sand from their windward to their leeward sides. As dunes were driven farther inland, new ones were built between them and the shore. Thus successive generations of dunes have been made and moved.

FIG. 25.—Dune covered with vegetation in the background. Fresh dune in the foreground to the left. This dune is migrating toward the forest, and will bury it if the advance continues. (Cowles.)

In San Francisco, on Cape Cod, in Holland, France, and other places measures are taken to prevent the migration of dunes, chiefly by planting the proper sorts of plants upon them. Some of the dunes about the head of the lake are far from shore, but it is not possible, in most places, to say how far their position is due to their migration inland, and how far to the recession of the shore from them. So long as dunes are moving, they are called *active*. Active dunes are well seen about Dune Park, where their advancing fronts are 20 to 100 feet high.

Professor Cowles reports the rise of sand, on one advancing dune slope which he observed, to have been a little more than 3 feet in 6 months, where the angle of slope was about 30°. This would mean an advance for the edge of about 10 feet in 6 months. Hardesty and Fulton report an advance of about 5 feet in 4 months (end of March to end of July, 1919), at one point about 1½ miles east of Dune Park.

FIG. 26.—Trees discovered after burial.[1] In the background to the right are living trees which have grown since the present surface was established. (Cowles.)

In the course of time vegetation gets a foothold on the dune sand, and vegetation, with its roots, tends to pin the sand down. Once well covered with vegetation, a dune is not likely to be shifted farther, and is said to be *fixed*, but even a fixed dune may have new sand drifted upon it. If sand accumulates on a slope covered with vegetation more rapidly than the plants grow upward, they are buried and killed. This has

[1] For an excellent discussion of the vegetation of the dunes, see articles by Dr. Henry C. Cowles in the *Botanical Gazette*, Vol. XXVII, 1898.

happened at various points about the head of the lake. If the vegetation on a fixed dune is destroyed, the dune may resume its migratory habit.

In many places trees have been buried by the advance of a dune (Fig. 25) on a forest. If the sand which buried the forest is blown on again before vegetation gets a foothold on it, the dead forest may be again discovered, resurrected, but not to life (Fig. 26). This also is to

FIG. 27.—Sand which once buried vegetation has been blown on, exposing the dead wood.

be seen about the head of the lake at various points. In many other places tree tops may be seen projecting up through the sand which has buried their lower parts. Some kinds of trees, as the cottonwood, continue to live and grow until their very tops are buried.

As dunes move inland and new ones are formed between the new position of the old dunes and the shore, depressions are left between the hills and ridges of sand. Some of them have roundish or elliptical shapes. Where the dunes are in the form of ridges, the depressions between are troughlike. Such depressions, whatever their shape, become the sites of marshes or ponds if they are sufficiently low. Much of the

rain which falls on the dunes themselves seeps out through the sand into these ponds and marshes.

From the foregoing it is evident that the older dunes are farther inland and the newer dunes near the shore. This is well seen in the vicinity of Miller and Dune Park. The older dunes farther inland are much more completely clothed with vegetation, and many of the dunes near the lake have little plant life upon them.

Destruction of dunes.—It happens, in some cases, that after dunes are well developed, currents of air are so directed by the hills and hollows that they excavate large depressions in the sand which already has been piled up. Locally such depressions are known as "blow-outs." There is a fine "blow-out" about a mile northeast of Dune Park. It is most easily reached by going directly to the lake from Dune Park Station, and then following the shore eastward about half a mile. There is a smaller "blow-out" about a quarter of a mile east of the larger one.

Size and topography.—Many of the dunes in the vicinity of Dune Park are as much as 100 feet high, and the highest approximately 200 feet. This is a rather exceptional height for dunes. Between Michigan City and St. Joseph, dunes are said to reach heights of more than 300 feet in a few places.

Nowhere within easy reach of Chicago is dune topography better shown than in the area northeast of Dune Park Station. A few hours spent in climbing over the hills of this region cannot fail to give a vivid and lasting impression of dune topography, where dune topography is well developed. From any high hill or ridge top of this region one is confronted by a veritable maze of steep-sloped hills and ridges. Interspersed among them are correspondingly deep depressions, many of which are marshy or swampy, and some of which contain intermittent lakelets. On the lakeward side of the dune maze is the beach, the source of sand for more dunes.

Singing sand.—Along the shore the beach sand often "sings," i.e., gives out a peculiar note as it is walked upon. The cause of the "singing" is not demonstrated, but it seems to be confined to times when the sand has a certain amount of moisture. It does not sing either when it is very wet, as after a rain, or just after waves have dashed over it, or when it is very dry; but when its surface is dry, and that just beneath the surface is moist, but not wet, the note is emitted.[1]

[1] This subject is discussed in *Science*, in 1919 and 1920, Vol. L, p. 493, and Vol. LI, p. 62.